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Analysis of Faculty Evaluation by Students as a Reliable Measure of Faculty Teaching Performance

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ANALYSIS OF FACULTY EVALUATION BY STUDENTS AS A RELIABLE MEASURE OF FACULTY TEACHING PERFORMANCE

by

ETIENNE TWAGIRUMUKIZA

Under the direction of Dr. Yichuan Zhao

ABSTRACT

Most American universities and colleges require students to provide faculty evaluation at end of each academic term, as a way of measuring faculty teaching performance. Although some analysts think that this kind of evaluation does not necessarily provide a good measurement of teaching effectiveness, there is a growing agreement in the academic world about its reliability. This study attempts to find any strong statistical evidence supporting faculty evaluation by students as a measure of faculty teaching effectiveness. Emphasis will be on analyzing relationships between instructor ratings by students and corresponding students' grades. Various statistical methods are applied to analyze a sample of real data and derive conclusions. Methods considered include multivariate statistical analysis, principal component analysis, Pearson's correlation coefficient, Spearman's and Kendall's rank correlation coefficients, linear and logistic regression analysis.

INDEX WORDS: Multivariate statistical analysis, Linear Regression, Logistic Regression, Principal component, Pearson's correlation, Spearman's rank correlation, Kendall's rank correlation.

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LIST OF ABREVIATIONS

PCA	Principal Component Analysis
SAS	Statistical Analysis System
SEF	Student Evaluation of Faculty
SRs	Student Ratings of Faculty
VIF	Variance Inflation Factor

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Chapter 1

INTRODUCTION

1.1 Purpose of the Study

In almost all American academic universities and colleges, at the end of each academic term, students are required to provide an evaluation of the faculty performance in delivering the teaching of courses completed at the end of the specific term. This kind of Student Evaluation of Faculty (SEF) is meant to measure or rate the effectiveness or performance of the faculty's teaching from the students' point of view.

Although some analysts think that this kind of evaluation does not necessarily provide a good measurement of teaching effectiveness, there is a growing agreement among researchers about the reliability of the evaluation. Does existing data support this assertion? Are ratings provided to faculty members positively correlated with students' performance on their exam? Is it possible to predict the faculty performance given SEF? The current study attempts to answer these questions.

Emphasis will be on analyzing relationships between instructor ratings by students and students' performance as measured by their grades in related courses. Various statistical methods shall be applied to analyze a sample of real data and derive conclusions. Statistical methods considered include multivariate statistical analysis, principal component analysis, Pearson's correlation, rank correlation coefficients such as Spearman's rank correlation coefficient and Kendall's rank correlation coefficient, linear regression analysis, and logistic regression analysis.

The study uses sample data extracted from existing databases of Georgia State University where course identifications have been masked and replaced by randomly generated numbers. The data is for the academic year 2008/2009. A total of 155 course-cases and 4,531 student-cases were considered by the study.

Due to the confidential character of data, it was not possible to obtain and use detailed data at student level. Only semi-aggregated data was made available that provide the number of students per course and their distribution by grade level for each course. With respect to Student Evaluation of Faculty (SEF), the study considers, for each course, average ratings by students for each of the 17 statements (Q1 to Q17).

1.2 Study Data

SEF ratings by students are provided by their students' respective agreements with each of the following 17 statements about the evaluated faculty member:

Q1. Explained the goals of this course clearly.
Q2. Explained the grading system clearly.
Q3. Gave assignments related to the goals of this course.
Q4. Followed the plan for the course as established in the syllabus.
Q5. Was well prepared.
Q6. Spoke in a way that communicated the subject in an understandable manner.
Q7. Responded constructively and thoughtfully to questions and comments.
Q8. Used class time effectively.
Q9. Had designated office and student appointment hours and was available to students during these times.
Q10. Assigned grades fairly.
Q11. Returned test results and evaluations of my work in a reasonable period of time (typically, 7-10 days or less is considered a reasonable College benchmark).
Q12. Met the class according to the published Schedule of Classes.
Q13. Stimulated my thinking and gave me new insights into the subject.

Q14. Related well to students.
Q15. Motivated me to learn.
Q16. Assigned readings (including the text(s)) that contributed to what I learned.
Q17. Considering both the limitations and possibilities of the subject matter and course, how would you rate the overall teaching effectiveness of the instructor?

Possible ratings are: 5 (Very High); 4 (High); 3 (Average); 2 (Below Average); 1 (Poor); and 0 (N/A).

The study also considers data on distribution of students' grades for each course being evaluated. Data transformation was carried out to translate grade levels into numeric data that can easily be manipulated and be used for analysis. The corresponding numerical grade values grades were defined as follows: grade A+ is 4.3, grade A is 4.0, grade A- is 3.7, grade B+ is 3.3, grade B=3.0, grade B- is 2.7, grade C+ is 2.3, grade C is 2.0, grade C- is 1.7, grade D is 1, and grade F is 0 (See Appendix C: Grading System Using +/ - System). Only grade A to F were retained for the study thereby excluding marginal cases of grades I, S, U, AU, W, WF, and OTH.

The SAS code for data transformation and data analysis is attached. Also attached are sample data for the study datasets. In our attempt to find any existing relationship between SEF and faculty performance, we will measure faculty performance by the course average grade per student.

Since a faculty member can teach more than a class, the evaluation made by students and corresponding student grades relate to the faculty member for a specific course delivered.

1.3 Previous Researches on the Subject

Given the use by university administrations of student evaluation of faculty to assess faculty performance and student learning, many researchers undertook to study the reliability of students' ratings of faculty as a measure of faculty performance (or students' learning). There were concerns about possible confounding factors that affect those ratings and thereby bias the results.

In 1976, Feldman's research findings on this subject led him to state that "currently available evidence cannot be taken as definitively establishing a bias in teacher evaluation due to the grades students receive or expect to receive in their courses, but neither is it presently possible to rule out such a bias".

In 1991, J. G. Nimmer and E. F. Stone carried out a study aimed at analyzing the "Effects of Grading Practices and Time of Rating on Student Ratings of Faculty Performance (SRs) and Student Learning". The findings from their research provide insights about confounding factors in faculty ratings by students and grading practices by instructors that can bias student evaluation of faculty as a reliable measure for faculty performance. The cited confounding factors include:

i. Class size.
ii. Anonymity of rating students.
iii. Time of rating (whether rating is carried out before or after students have their final grade in the course).
iv. Type of the course, whether a major course or rather a minor one.
v. Student motivation.
vi. Learning effect as students who learn more get higher grades.

vii. Effect of expected versus received grades, with students receiving less than expected grade providing unfavorable ratings to related faculty members.

viii. Difficulty of the courses taught which can lead students in providing biased ratings to faculty teaching effectiveness.

ix. Student enrollment type in the course, whether a required or election course.

x. Grading practices by instructors, some implementing grading leniency while others rather prefer grading stringency.

A quasi-experimental design by J. G. Nimmer and E. F. Stone on the effect of grading practices showed that as grading stringency increased, students responded with a systematic retaliation of decreased ratings for concerned faculty members.

The two researchers concluded that “considerable caution should be exercised by individuals who use SRs as a basis for personnel decision making. Administrative decisions about faculty should be based on data that are as free of bias as is practically possible”.

Hence, if confounding factors are present in the data that is used to study possible relationship between Student Evaluation of Faculty and Faculty Performance, this could make it difficult to discern and model a reliable relationship between student evaluation of faculty and student grades as a measure of faculty performance.

In view of the above, it appears that the presence of confounding factors constitute a big impediment to finding a reliable predictive model for Faculty Performance on basis of Student Evaluation of Faculty (SEF).

Chapter 2

DATA EXPLORATION AND SAMPLING

2.1 Data Exploration

It is always a good practice to proceed with data exploration and identify any missing data and get summary statistics that can reveal some general characteristics of the data to be analyzed.

The SAS proc univariate is run to produce the histogram representing the distribution of course grade average. Figure 2.1 below shows that the distribution for the course grade average is left-skewed. This signals existence of extreme observations to the left tail that could be potential outlier observations.

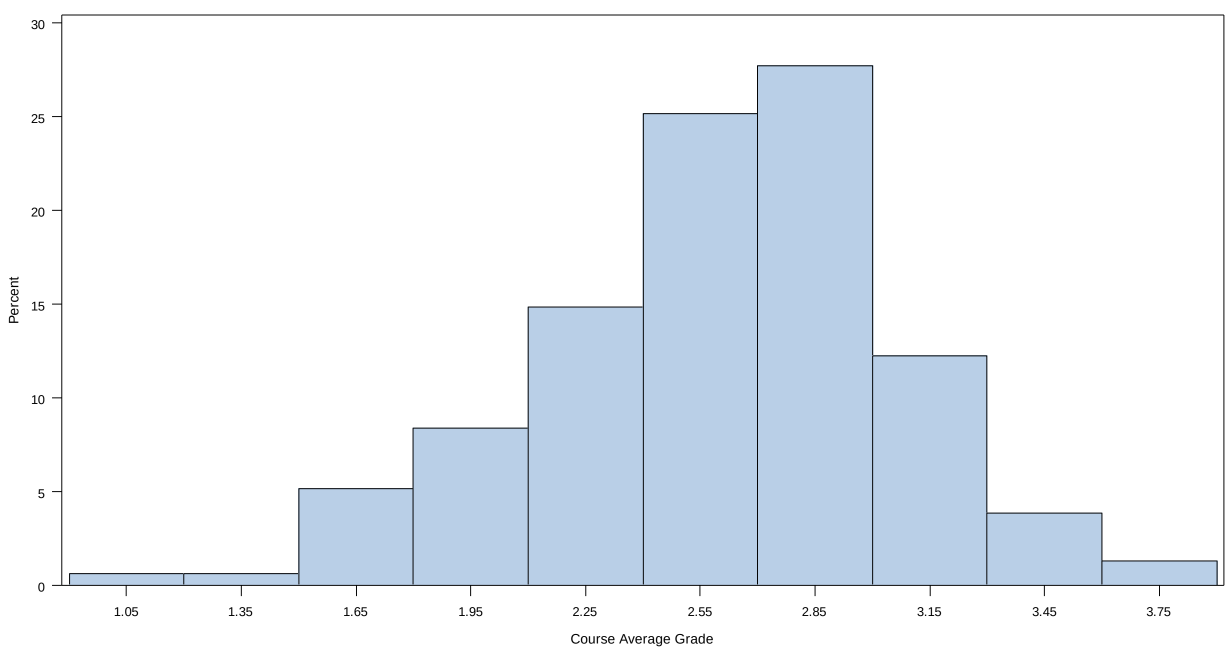


Figure 2.1 Course Grade Average Distribution

For each course, the average SEF was computed based on responses for each of the 17 statements. Figure 2.2 below provides the distribution of the Course SEF Average. We observe that it is left-skewed too like the distribution of course grade average shown above. This is an indication of potential extreme observations near 2.5.

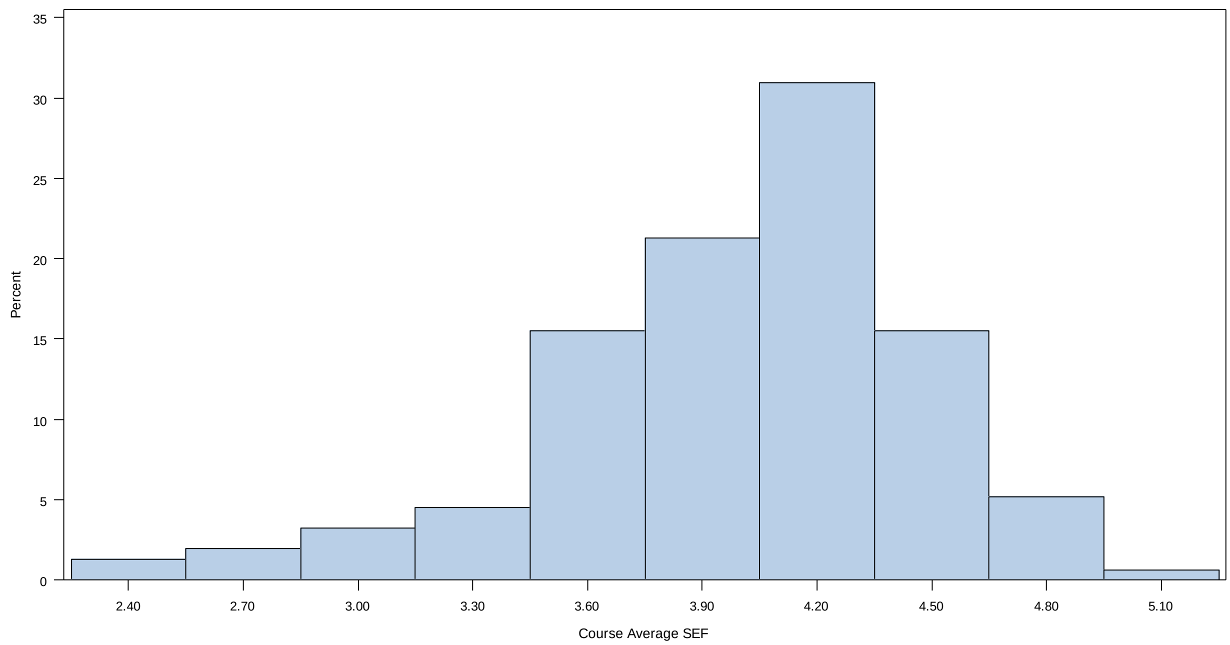


Figure 2.2 Course SEF Average Distribution

We also carry out the analysis of possible missing data for grade distribution and SEF distributions. We recall that for each course we have the distribution of students by grade level namely: A+, A, A-, B+, B, B-, C+, C, C-, D, and F.

Table 2.1 shows that, in general, there were more students with grade C, followed by students with grade B and then A. The grade level C- attracted the lowest number of students. For all grade levels, there is at least one course without a single student with the specific grade (minimum number of students=0). No missing data observed.

Table 2.1: Basic Summary Statistics for Student Grade Levels

Grade Level	Number of Obs. (# of Courses)	Number of Missing Obs.	Total Number of Students	Average Number of Students with a Grade Level in per Course	Minimum Number of Students per grade level	Maximum Number of Students per grade level
Aplus	155	0	339	2	0	10
A	155	0	492	3	0	15
Aminus	155	0	484	3	0	12
Bplus	155	0	448	3	0	13
B	155	0	565	4	0	12
Bminus	155	0	391	3	0	12
Cplus	155	0	289	2	0	6
C	155	0	613	4	0	12
Cminus	155	0	9	0	0	2
D	155	0	407	3	0	13
F	155	0	494	3	0	14
Total			4,531			

With respect to Student Evaluation of Faculty, Figure 2.3 below provides SEF Average Rating per Course for the 155 courses covered by the study. We notice that the average rating per statement varies. Statement Q12 followed by Q11 in general are more rated than other statements. Statements Q12 and Q11 represent “Faculty Member Met the class according to the published Schedule of Classes” and “Faculty Member Returned test results and evaluations of my work in a reasonable period of time”, respectively.

The minimum average SEF (3.51) corresponds to Q15 which stands for “Faculty Member Motivated me to learn”. It is followed by Q14 (Faculty Member Related well to students) and Q6 (Faculty Member Spoke in a way that communicated the subject in an understandable manner).

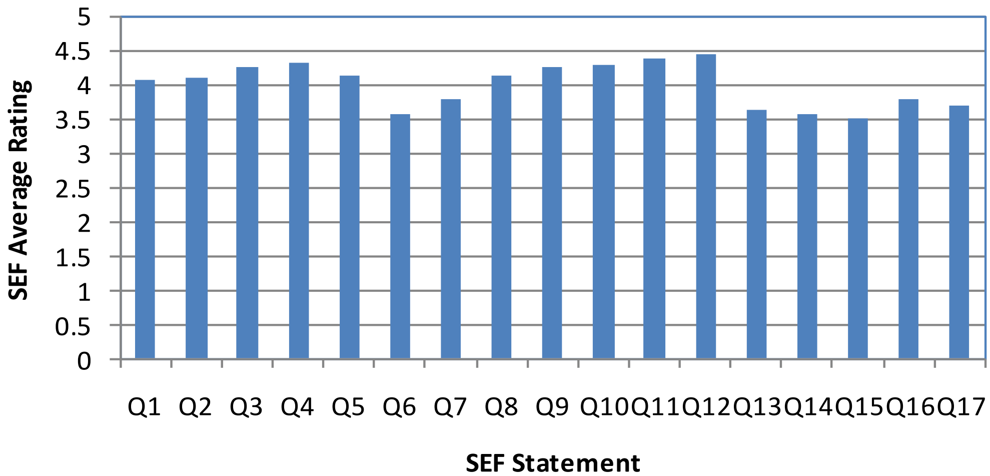


Figure 2.3 SEF Average Rating per Course

Table 2.2 shows that there is no missing data for the SEF variables. It also reveals that the average statement rating score varies from 1.7 to 5. In the next chapters we will attempt to use existing statistic methods to study any existing relationship between SEF and the faculty performance (as measured by corresponding course grade average per student).

Table 2.2: Basic Summary Statistics for Student Evaluation of Faculty (SEF)

	SEF Statement	Overall Course Average SEF Rating	Number of Obs. (# of Courses)	Number of Missing Obs.	Minimum Average Rating per Course	Maximum Average Rating per Course
Q1	Faculty Member Explained the goals of this course clearly.	4.07	155	0	1.9	5
Q2	Faculty Member Explained the grading system clearly.	4.10	155	0	1.8	5
Q3	Faculty Member Gave assignments related to the goals of this course.	4.25	155	0	2.7	5
Q4	Faculty Member Followed the plan for the course as established in the syllabus.	4.31	155	0	3.0	5
Q5	Faculty Member Was well prepared.	4.14	155	0	2.5	5
Q6	Faculty Member Spoke in a way that communicated the subject in an understandable	3.58	155	0	1.9	5
Q7	Faculty Member Responded constructively and thoughtfully to questions and comments.	3.79	155	0	2.1	5
Q8	Faculty Member Used class time effectively.	4.13	155	0	2.6	5
Q9	Faculty Member Had designated office and student appointment hours and was available to students during these times.	4.25	155	0	2.2	5
Q10	Faculty Member Assigned grades fairly.	4.27	155	0	2.9	5
Q11	Faculty Member Returned test results and evaluations of my work in a reasonable period of time (typically, 7-10 days or less is considered a reasonable College benchmark).	4.37	155	0	2.6	5
Q12	Faculty Member Met the class according to the published Schedule of Classes.	4.45	155	0	3.0	5
Q13	Faculty Member Stimulated my thinking and gave me new insights into the subject.	3.63	155	0	1.8	5
Q14	Faculty Member Related well to students.	3.58	155	0	1.7	5
Q15	Faculty Member Motivated me to learn.	3.51	155	0	1.7	5
Q16	Faculty Member Assigned readings (including the text(s)) that contributed to what I learned.	3.80	155	0	2.0	5
Q17	Faculty Member Considering both the limitations and possibilities of the subject matter and course, how would you rate the overall teaching effectiveness of the instructor?	3.68	155	0	2.0	5

2.2 Data Sampling

The approach used is intended to get a development (or training) sample used to build the model and a separate validation sample that would be applied to validate the model. Given the limited number of cases (155 courses), and the need to have ability to compare results in development and validation samples, the following criteria were used for the selection of samples.

The entire sample consists of 155 MATH courses in the College of Science and Arts for the 2009 Fall semester with a total of 4,531 students having a grade between A+ and F. The 155 courses are grouped into 11 course sections.

In order to build a development sample and a validation sample, we decided to use the process of stratified random sampling. Two course sections with 1 or 2 courses were excluded from the sampling to retain only those sections that can be represented in both development and validation samples. This leaves us with 9 course sections with 152 courses and 4,464 students. The sample rate for the development sample is approximately 65 percent. The remaining courses (about 35 percent) constitute the validation sample.

The SAS proc surveyselect is used to select the development sample. The validation sample is derived as a set of courses not selected for the development sample. The stratified random sampling selected 102 courses with 2,948 students for the development sample, and 50 courses with 1,516 students for the validation sample. The sampling data is summarized in Table 2.3 below.

If a model is built to predict faculty performance on basis of known SEF, then the model will be validated by applying the parameters of the predictive models to the validation sample.

Appropriate statistical methods shall be used to analyze the model adequacy and measure how the model fits predicted faculty performance values to actual observed values of faculty performance. Those statistics would include Residual analysis, analysis of the estimates' correlation matrix, analysis of collinearity, R-square, normality test, etc. To validate the model on validation sample we would use Residual analysis and the analysis of plots of observed values and fitted values of faculty performance.

Table 2.3 Summary Sampling Data

Course Section	Development Sample		Validation Sample		All Samples	
	Number of Courses	Number of Students	Number of Courses	Number of Students	Number of Courses	Number of Students
0099	2	80	1	46	3	126
1070	19	753	9	343	28	1,096
1101	40	981	21	568	61	1,549
1111	15	392	8	233	23	625
1113	11	327	5	150	16	477
2008	2	47	1	40	3	87
2211	7	194	3	87	10	281
2212	4	121	1	39	5	160
2215	2	53	1	10	3	63
Total	102	2,948	50	1,516	152	4,464

Chapter 3

PRINCIPAL COMPONENTS ANALYSIS

3.1 Review of the Method

We recall that the purpose of the study is to establish whether there exists any correlation between Student Evaluation of Faculty (SEF) and faculty member performance as measured by grades obtained by students in the taught course. With 17 variables for SEF and 6 grade levels, there is need to carry out data reduction in such a way that the interpretation of results is simplified to derive useful insights.

SAS enables us to apply the principles of principal component analysis (PCA) to achieve the sought data reduction. Our approach is to apply PCA on the 17 variables for SEF, and without much of information loss, derive few factors that can be used to study any existing relationship between SEF and faculty performance through correlation and regression models.

Principal Component Analysis (PCA) is a statistical process that concerns situations where you have data on a number of observable variables and want to get a smaller number of artificial variables that can still explain most of the data variability. These unobservable variables which are called principal components are derived usually through linear combinations of considered observable variables in a way that data reduction is achieved while keeping most of the variance in observed variables.

3.2 Application of the Method

The application of PCA method is relevant in our study and can be applied to achieve parsimonious models. Let us consider the 17 average ratings of the faculty provided by students according to the 17 statements (Q1 to Q17) referred to above as a set of independent variables representing SEF. PCA analysis can be applied to explore any latent constructs that classify the SEFs in group that are measuring a same aspect, such as fair grading applied by the faculty. PCA can also be used to reduce the 17 independent variables to fewer principal component variables that can be used as potential predictors in our search for any existing relationship between SEF and faculty performance.

The Appendix D (SAS Output of Proc Factor for Principal Component Analysis) shows the output derived from running the SAS proc factor. The results reveal that only 2 principal components are needed to explain most of the variations in the data for the 17 SEF variables. About 88 percent of the variance is explained by only 2 principal components.

With orthogonal transformation of Factors, the PCA enables us to see two major constructs: the construct that groups together Q3 to Q5, Q8 to Q12 to lean on Factor 1 and the construct represented by Factor 2 and combines Q6, Q7, and Q13 to Q17. Table 3.1 provides the loadings for the rotated factors.

Factor 1 may be considered as a reflection of faculty members' preparedness and delivery of effective teaching and grading fairness while factor 2 reflects how students view faculty's effectiveness in interacting with them to encourage and motivate their work.

In chapter 6 we will attempt to predict faculty performance using the two principal components (factors) as parsimoniously selected predictors.

Table 3.1 Summary of Development Sample SEF Principal Components

SEF	SEF Lable	Factor1 Loadings (%)	Factor2 Loadings (%)
Q1	Faculty Member Explained the goals of this course clearly.	65	66
Q2	Faculty Member Explained the grading system clearly.	70	60
Q3	Faculty Member Gave assignments related to the goals of this course.	79	48
Q4	Faculty Member Followed the plan for the course as established in the syllabus.	82	44
Q5	Faculty Member Was well prepared.	74	60
Q6	Faculty Member Spoke in a way that communicated the subject in an understandable manner.	43	85
Q7	Faculty Member Responded constructively and thoughtfully to questions and comments.	55	79
Q8	Faculty Member Used class time effectively.	77	52
Q9	Faculty Member Had designated office and student appointment hours and was available to students during these times.	78	42
Q10	Faculty Member Assigned grades fairly.	81	48
Q11	Faculty Member Returned test results and evaluations of my work in a reasonable period of time (typically, 7-10 days or less is considered a reasonable College benchmark).	88	29
Q12	Faculty Member Met the class according to the published Schedule of Classes.	76	40
Q13	Faculty Member Stimulated my thinking and gave me new insights into the subject.	37	89
Q14	Faculty Member Related well to students.	43	87
Q15	Faculty Member Motivated me to learn.	42	88
Q16	Faculty Member Assigned readings (including the text(s)) that contributed to what I learned.	50	75
Q17	Faculty Member Considering both the limitations and possibilities of the subject matter and course, how would you rate the overall teaching effectiveness of the instructor?	51	83

Chapter 4

PEARSON'S CORRELATION

4.1 Definition of the Method

The Pearson correlation is used to measure the strength of linear dependence between two variables. In a population, the correlation between two variables is defined as the covariance of the two variables divided by the product of their standard deviations.

In a sample, given two variables X and Y in a sample for which we are interested to study their linear relationship, the sample Pearson's correlation coefficient between X and Y is defined as follows:

$$r = \frac{\sum_{i=1}^{n}(X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \overline{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \overline{Y})^2}}$$

, where i is an element of the sample and n is the sample size.

4.2 Application of the method

The SAS Proc Corr allows us to compute the correlation coefficient between variables in a dataset. We apply it to compute sample correlation coefficient between each of the SEF variables, Q1 to Q17 (the X's), and faculty performance measured by course grade average per student, grade_avg (the Y). There are 102 observations for each SEF ratings and the course grade average. Each observation corresponds to a course in the Sample.

The SAS Output is shown in Appendix E. Table 4.1 hereafter provides the results. The highest correlation is between course grade average and Q10 (Faculty Member Assigned grades fairly) but it is still very weak. We conclude that with Pearson's correlation coefficient there is no evidence of any strong relationship between SEF variables and faculty performance (Course Grade Average per Student).

Table 4.1 Pearson Correlation Coefficients between the SEF and Course Grade Average per Student (grade_avg)

	SEF Variables	Pearson Correlation Coefficient		SEF Variables	Pearson Correlation Coefficient
Q1	Faculty Member Explained the goals of this course clearly.	0.05480	Q10	Faculty Member Assigned grades fairly.	0.22069
Q2	Faculty Member Explained the grading system clearly.	0.08845	Q11	Faculty Member Returned test results and evaluations of my work in a reasonable period of time (typically, 7-10 days or less is considered a reasonable College benchmark).	0.20730
Q3	Faculty Member Gave assignments related to the goals of this course.	0.17478	Q12	Faculty Member Met the class according to the published Schedule of Classes.	0.12439
Q4	Faculty Member Followed the plan for the course as established in the syllabus.	0.04737	Q13	Faculty Member Stimulated my thinking and gave me new insights into the subject.	0.02850
Q5	Faculty Member Was well prepared.	0.09074	Q14	Faculty Member Related well to students.	0.07099
Q6	Faculty Member Spoke in a way that communicated the subject in an understandable manner.	0.02270	Q15	Faculty Member Motivated me to learn.	0.03926
Q7	Faculty Member Responded constructively and thoughtfully to questions and comments.	0.06990	Q16	Faculty Member Assigned readings (including the text(s)) that contributed to what I learned.	0.08979
Q8	Faculty Member Used class time effectively.	0.07109	Q17	Faculty Member Considering both the limitations and possibilities of the subject matter and course, how would you rate the overall teaching effectiveness of the instructor?	0.04188
Q9	Faculty Member Had designated office and student appointment hours and was available to students during these times.	0.07028			

Chapter 5

RANK CORRELATION COEFFICIENTS

A rank correlation coefficient is used to study the relationships between rankings on the measurements of same elements. It provides a measurement of the correspondence between two rankings as well as the associated statistical significance.

5.1 Spearman's Rank Correlation Coefficient

5.1.1 Definition of the Method

The Spearman correlation coefficient is a correlation coefficient between ranked variables X and Y. Let say that u_i, v_i are the ranks for X and Y respectively for the observation i. The Spearman's Rank Correlation Coefficient is provided by the following formula which is similar to the Pearson's correlation coefficient where observed values of x_i and y_i are replaced by the corresponding ranks u_i, v_i of X and Y for observation i.

The formula is: $\mathrm{r} = \dfrac{\sum_i (u_i - \bar{u})(v_i - \bar{v})}{\sqrt{\sum_i (u_i - \bar{u})^2 \sum_i (v_i - \bar{v})^2}}$, where u_i, v_i are ranks for x_i and y_i respectively. In case there are ties, all equal values are assigned the same rank. In practice, if no ties of ranks are observed, the formula for Spearman's rank correlation coefficient takes the following simplified form:

$\rho = 1 - \frac{6\sum_1^n d_i^2}{n(n^2-1)}$, where $\mathrm{d_i = u_i - v_i}$ (the difference of ranks for $\mathrm{x_i}$ and $\mathrm{y_i}$) and n is the number of observations in the sample.

Here is the proof of the simplified form for the Spearman's rank correlation coefficient formula:

The sum of squared differences of X and Y ranks $\sum_1^n d_i^2$ has a maximum value if there is a perfect negative correlation between ranks of X and Y. The minimum possible value is attained if there is a perfect positive correlation of ranks, where $\sum_1^n d_i^2 = 0.$

If n is even, the maximum possible value is double the sum of the squares for the first p odd natural numbers with p=n/2.

$$\sum_1^n d_i^2 = 2\sum_{k=0}^{k=p} (2\mathrm{k}-1)^2, \text{ where } \mathrm{p = n/2}.$$

If n is odd, then the maximum possible value for the sum of the squared rank difference $\sum_1^n d_i^2 = 2\sum_{k=0}^{k=p} \mathrm{k}^2$, where $\mathrm{n = 2p+1}$, and hence $\mathrm{p = (n-1)/2}$.

We know that the sum of the squares for the first n natural numbers is provided by the following relation:

$$\sum_0^n k^2 = 1^2 + 2^2 + 3^2 + 4^2 + \ldots + n^2 = \frac{n}{6}(n+1)(2n+1). \quad \text{(Relation 1)}$$

We also know that the sum of the squares for the first n odd natural numbers is as follows:

$$\sum_0^n (2k-1)^2 = 1^2 + 3^2 + 5^2 + \ldots + (2n-1)^2 = \frac{n}{3}(2n-1)(2n+1). \quad \text{(Relation 2)}$$

The proof for relations 1 and 2 are in Appendix H.

If the sample size n is even, let n=2p, where p is a natural number.

$$\text{By relation 2 we get}: \sum_1^n d_i^2 = 2\sum_{k=0}^{k=p}(2\mathrm{k}-1)^2 = 2\frac{p(2p-1)(2p+1)}{3}, \text{ where } \mathrm{p} = \mathrm{n}/2.$$

Replacing p by n/2 we get:

$$\boxed{\sum_1^n d_i^2 = 2\frac{\frac{\mathrm{n}}{2}(n-1)(n+1)}{3} = \frac{\mathrm{n}(\mathrm{n}^2-1)}{3}.}$$

In case n is odd, then let p=(n-1)/2. We need to compute the sum of the squares for the first p even natural numbers.

$$\sum_1^n d_i^2 = 2\sum_{k=0}^{k=p}\mathrm{k}^2, \text{ where } \mathrm{p} = (\mathrm{n}-1)/2.$$

When n is odd, there are p even number between 0 and n and p+1 odd numbers between 0 and n, where p=(n-1)/2. Relations 1 and 2 above allow us to deduce the sum of the squares for the first n even natural numbers. This can be obtained by subtracting from the total sum of the squares for the first n natural numbers, the sum of the squares for the first p+1 odd numbers.

$$\sum_1^n d_i^2 = 2\sum_{k=0}^{k=p}\mathrm{k}^2 = 2(\frac{n}{6}(n+1)(2n+1) - \frac{(p+1)}{3}(2(p+1)-1)(2(p+1)+1)),$$

where p=(n-1)/2.

$$\sum_1^n d_i^2 = 2(\frac{n}{6}(n+1)(2n+1) - \frac{(p+1)}{3}(2p+1)(2p+3))$$

$$\sum_1^n d_i^2 = 2\left(\frac{n}{6}(n+1)(2n+1) - \frac{n(n+1)(n+2)}{6}\right) = \frac{n(n+1)(2n+1-(n+2))}{3}$$

$$\sum_1^n d_i^2 = \frac{n(n+1)(n-1)}{3} \Longrightarrow \boxed{\sum_1^n d_i^2 = \frac{n(n^2-1)}{3}}$$

We have proved that for any sample size n, the maximum possible value for sum of the squares for rank differences of X and Y is given by the formula $\boxed{\max \sum_1^n d_i^2 = \frac{n(n^2-1)}{3}}$.

The ratio $\frac{\sum_1^n d_i^2}{\frac{n(n^2-1)}{3}} = \frac{3\sum_1^n d_i^2}{n(n^2-1)}$ will equal 0 if there is perfect positive correlation of ranks, 1 if ranks are perfectly negative correlated, and 0.5 if there is perfect lack of rank correlation. If we double the ratio and have $\boxed{\rho = 1 - \frac{6\sum_1^n d_i^2}{n(n^2-1)}}$, we get a good measure for rank correlation that takes the value of 1 if there is perfect positive correlated between ranks, -1 in case of perfect negative correlation, and 0 in case of zero correlation between ranks.

Thus, if there are no ties, the simplified formula $\boxed{\rho = 1 - \frac{6\sum_1^n d_i^2}{n(n^2-1)}}$ can replace the general one to measure the Spearman's Rank Correlation Coefficient between 2 variables.

5.1.2 Application of the Method

SAS provides the proc corr that we can use to compute the Spearman's Rank Correlation Coefficient between ranks of pair variables representing the SEF and faculty performance (course grade average per student). The SAS output for Spearman's Rank Correlation Coefficients is in Appendix F. The summary results for Spearman's ranks correlation coefficients are provided in Table 5.1 below.

As it can be seen from this table, no strong correlation between SEF variables and course grade average per student is observed. The highest rank correlation coefficient of 0.22069 corresponds to Q10 (Faculty Member Assigned grades fairly). Hence, no strong evidence found about any existing relationship between Student Evaluation of Faculty and Faculty Performance.

Table 5.1 Spearman's Correlation Between SEF Variables and Grade Variables

	SEF Variables	Spearman's Rank Correlation Coefficient		SEF Variables	Spearman's Rank Correlation Coefficient
Q1	Faculty Member Explained the goals of this course clearly.	0.05480	Q10	Faculty Member Assigned grades fairly.	0.22069
Q2	Faculty Member Explained the grading system clearly.	0.08845	Q11	Faculty Member Returned test results and evaluations of my work in a reasonable period of time (typically, 7-10 days or less is considered a reasonable College benchmark).	0.20730
Q3	Faculty Member Gave assignments related to the goals of this course.	0.17478	Q12	Faculty Member Met the class according to the published Schedule of Classes.	0.12439
Q4	Faculty Member Followed the plan for the course as established in the syllabus.	0.04737	Q13	Faculty Member Stimulated my thinking and gave me new insights into the subject.	0.02850
Q5	Faculty Member Was well prepared.	0.09074	Q14	Faculty Member Related well to students.	0.07099
Q6	Faculty Member Spoke in a way that communicated the subject in an understandable manner.	0.02270	Q15	Faculty Member Motivated me to learn.	0.03926
Q7	Faculty Member Responded constructively and thoughtfully to questions and comments.	0.06990	Q16	Faculty Member Assigned readings (including the text(s)) that contributed to what I learned.	0.08979
Q8	Faculty Member Used class time effectively.	0.07109	Q17	Faculty Member Considering both the limitations and possibilities of the subject matter and course, how would you rate the overall teaching effectiveness of the instructor?	0.04188
Q9	Faculty Member Had designated office and student appointment hours and was available to students during these times.	0.07028			

5.2 Kendall's Rank Correlation Coefficient

5.2.1 Definition of the Method

The Kendall rank correlation coefficient is used to measure the association between two variables and is often used to test for statistical dependence.

Given pairs of observations of two measured variables X and Y on the same elements of a sample, say (x_i, y_i), the Kendall ranks process consists in identifying concordance and discordance between various pairs of X and Y observations. For each i and j elements of the sample, we consider the pair (x_i, y_i) and (x_j, y_j). If $x_i<x_j$ and $y_i<y_j$ then the pair are said to be concordant. Otherwise it is discordant.

The Kendall rank correlation coefficient is thus computed as follows:

$$\tau = \frac{\text{(Number of concordant pairs) - (Number of discordant pairs)}}{\text{Total number of possible pairs}}$$

$$\tau = \frac{\text{(Number of concordant pairs) - (Number of discordant pairs)}}{\frac{1}{2}\mathrm{n(n-1)}}$$

In our study, the pairs are made of observations from the Y variable (Faculty performance measured by course grade average per student) and from each of the independent variables Q1 to Q17 that represent the student evaluation of faculty. For each set of Qk and Y (where k=1 to 17), the total number of possible pairs (q_{ki}, y_i) and (q_{kj}, y_j) is $\frac{\mathrm{n(n-1)}}{2} = \frac{100*101}{2} = 5050\ \text{pairs}$.

5.2.2 Application of the Method

The SAS Proc Corr is used to compute the Kendall rank correlation coefficient between Course grade average per student and each of the 17 independent variables Q1 to Q17. Table 5.2 below contains the summary results. The highest correlation is between Course grade average per student and Q10 (Faculty Member Assigned grades fairly) where it takes the value of 0.22069. It is followed by correlation with Q11 (Faculty Member Returned test results and evaluations of my work in a reasonable period of time), with a correlation coefficient of 0.20730.

With such results, we are unable to find evidence of any existing strong association between SEF and Faculty Performance.

Table 5.2 Kendall's Correlation Between SEF Variables and Grade Variables

	SEF Variables	Spearman's Rank Correlation Coefficient			SEF Variables	Spearman's Rank Correlation Coefficient
Q1	Faculty Member Explained the goals of this course clearly.	0.05480		Q10	Faculty Member Assigned grades fairly.	0.22069
Q2	Faculty Member Explained the grading system clearly.	0.08845		Q11	Faculty Member Returned test results and evaluations of my work in a reasonable period of time (typically, 7-10 days or less is considered a reasonable College benchmark).	0.20730
Q3	Faculty Member Gave assignments related to the goals of this course.	0.17478		Q12	Faculty Member Met the class according to the published Schedule of Classes.	0.12439
Q4	Faculty Member Followed the plan for the course as established in the syllabus.	0.04737		Q13	Faculty Member Stimulated my thinking and gave me new insights into the subject.	0.02850
Q5	Faculty Member Was well prepared.	0.09074		Q14	Faculty Member Related well to students.	0.07099
Q6	Faculty Member Spoke in a way that communicated the subject in an understandable manner.	0.02270		Q15	Faculty Member Motivated me to learn.	0.03926
Q7	Faculty Member Responded constructively and thoughtfully to questions and comments.	0.06990		Q16	Faculty Member Assigned readings (including the text(s)) that contributed to what I learned.	0.08979
Q8	Faculty Member Used class time effectively.	0.07109		Q17	Faculty Member Considering both the limitations and possibilities of the subject matter and course, how would you rate the overall teaching effectiveness of the instructor?	0.04188
Q9	Faculty Member Had designated office and student appointment hours and was available to students during these times.	0.07028				

Chapter 6

LINEAR REGRESSION ANALYSIS

6.1 Review of the Method

Linear Regression is a statistical technique used to investigate and model relationship between a variable called dependent variable and one or more independent variables called predictors.

In general, linear regression models are fitted using the least squares technique. However, linear regression models can be developed using other techniques that minimize the lack of fit.

Given a set of observations y_i of the dependent variable Y that we want to predict, and corresponding observations x_{i1}, x_{i2}, …, x_{ip} of the independents variables X1, X2, …Xp considered as predictors of Y, ε is an n x 1 vector of random errors, the linear regression model is defined as: $y_i = \beta_1 x_{i1} + \ldots + \beta_p x_{ip} + \varepsilon_i$, where i =1,… n and Beta coefficients are estimates derived from solving the least-square normal equations.

The least-square normal equations solution is: $\hat{\beta} = (X'X)^{-1} X'y$, where $\hat{\beta}$ is a p x 1 vector of coefficient estimates, y is a n x 1 vector of n observation of the dependent variable Y, and X is an n x p vectors of observations from the p independent variables.

6.2 Application of the Method

We recall that we have a sample of 102 courses. The variable of interest that we need to predict is Faculty Performance measured by the Course Average Grade per Student. In the sample dataset, this dependent variable is named “grade_avg”. The potential predictors include Factor1 and Factor2 derived from the principal component analysis we carried out above and the SEF variable Q1 to Q17.

The 17 SEF variables are average students’ ratings of faculty provided as responses to each of the 17 statements of the faculty evaluation form by students. The full description of these statements is provided in Chapter 1, page 2.

The SAS Proc Reg is used to attempt to build a linear regression model between the dependent variable defined above and the potential predictors. We first try to fit a linear model with the principal components Factor1 and Factor2. Then we shall try a linear model that regresses the course grade average per student against the 17 course average ratings of faculty by students. We also use variable transformations and fit a model.

Model adequacy shall be carried out. Especially, we shall check for errors’ constant variance and the condition for uncorrelated errors to see if these assumptions are not violated. Test of normality also will be made though the normal probability plot. Parameter estimates will be checked for their statistical significance, for their sign, their stability, and existence of any multicollinearity issues, through the analysis of estimates correlation, their respective variance inflation factors, and through residual analysis.

Finally, the model built with the development sample shall be applied to the validation sample to validate its predictability and confirm whether the model estimates are not random. If the model fits were observed values in the validation sample, this will constitute a good proof that the model can be applied to predicted faculty performance for any sample drawn from the population under study.

The variance inflation factor is provided by the formula: $\boxed{VIF_j = \frac{1}{1 - \mathrm{R}_j^2}}$, where R_j^2 is the coefficient of multiple determination resulting from regressing the j^{th} regressor on the other remaining regressors. A regressor that is linearly dependent with other regressors has a large R_j^2 close to 1, hence a large VIF. This provides a good indication of multicollinearity issues that may exist in the model.

6.2.1 Fitting a Model with Principal Components

Attempt to build a model with the principal components failed. No variable met the condition of inclusion into the model (the p-value=0.05 condition). The SAS Proc Reg output is in Appendix I.

6.2.2 Linear Model with the SEF Variables

We start the model building with the stepwise technique to get regressors into the model. Table 6.1 provides the summary results for the initial model’s estimates. The full SAS output is attached in Appendix J. The overall model test is significant. All the coefficient estimates are statistically significant. The R-square is 0.9686. However the

C(p) with its value of 14.25 is relatively very high compared to an expected value close to the number 4 of regressors in the model.

The highest variance inflation factor is 550.6 and corresponds to Q10 (Faculty Member Assigned grades fairly). From Appendix J, we also observe a relatively high correlation between Q10 and Q11 (Faculty Member Returned test results and evaluations of my work in a reasonable period of time) of -0.6840. It is the only high correlation observed between estimates of beta coefficients. This high correlation between Q10 and Q11 together with relatively high VIF for Q10 and Q11 indicates that there is a problem of multicollinearity involving Q10 and Q11. We shall try to include in the model interaction terms for regressors already in the model.

Table 6.1 Linear Regression Initial Model Estimates

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Q1	-0.31926	0.15754	-2.03	0.0454	192.22
Q8	-0.47466	0.18862	-2.52	0.0135	281.61
Q10	0.94109	0.25527	3.69	0.0004	550.63
Q11	0.41021	0.19547	2.10	0.0384	336.60

6.2.3 Model with Interaction Terms Added

In an attempt to stabilize model estimates, we rerun the model with interaction terms of regressors already in the model. We proceed by first including all possible interaction terms for the four variables already in the model. Then interaction terms are removed from the model one by one by eliminating first those whose parameter estimates are non significant and have the highest p-values.

Each time that an interaction term is removed, the model is rerun to insure that parameter estimates for the remaining variables and interaction terms are all significant. The related SAS output is in Appendix K.

The introduction of all interaction terms into the model provided the estimates shown in table 6.2 below.

Table 6.2 Linear Regression Estimates with All Interaction Terms in the Model

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Q1	4.24495	8.81782	0.48	0.6314	600486
Q8	-0.13654	3.1573	-0.04	0.9656	78688
Q10	-15.59637	17.36593	-0.9	0.3716	2541225
Q11	14.43488	13.26509	1.09	0.2795	1545789
intq1q8	-1.18199	2.60968	-0.45	0.6517	969195
intq1q10	3.67866	3.51917	1.05	0.2987	1861932
intQ1Q11	-4.40583	4.24134	-1.04	0.3017	2797674
intq8q10	3.94693	4.44992	0.89	0.3775	3043583
intq8q11	-3.39412	3.62638	-0.94	0.3518	2096190
intq10q11	0.25359	2.31936	0.11	0.9132	909187
intQ1Q8Q10	-0.86674	0.87826	-0.99	0.3264	2199261
intQ1Q8Q11	1.0555	1.08518	0.97	0.3334	3459091
intQ8Q10Q11	-0.06248	0.56965	-0.11	0.9129	1027183

With all interaction terms in the model, we realize that all parameter estimates become non significant. The interaction parameter estimate with the highest p-value corresponds to the interaction term intQ10Q11. We remove this term from the model and rerun it. Table 6.3 provides a summary of the resulting parameter estimates.

Table 6.3 Linear Regression Estimates with the Interaction Term intQ10Q11 Removed from the Model

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Q1	3.33131	2.80011	1.19	0.2373	61225
Q8	-0.31225	2.70275	-0.12	0.9083	58302
Q10	-14.48275	13.98799	-1.04	0.3033	1667063
Q11	14.30214	13.13671	1.09	0.2792	1532839
intq1q8	-0.94065	1.38457	-0.68	0.4986	275842
intq1q10	3.64628	3.48738	1.05	0.2986	1848743
intQ1Q11	-4.13335	3.41303	-1.21	0.229	1831740
intq8q10	3.69606	3.79179	0.97	0.3323	2234412
intq8q11	-3.32094	3.54446	-0.94	0.3513	2024785
intQ1Q8Q10	-0.85881	0.87044	-0.99	0.3265	2184243
intQ1Q8Q11	0.98515	0.86906	1.13	0.26	2243117
intQ8Q10Q11	-0.00586	0.23609	-0.02	0.9803	178400

We observed that the parameter estimate associated with the interaction term intQ8Q10Q11 (interaction term between Q8, Q10 and Q11) has the highest p-value among non significant interaction terms. We remove this term from the model and rerun it. Table 6.4 provides summary statistics about the resulting parameter estimates.

Table 6.4 Linear Regression Estimates with the Interaction Term intQ8Q10Q11 Removed from the Model

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Q1	3.27685	1.72999	1.89	0.0614	23630
Q8	-0.27555	2.24995	-0.12	0.9028	40852
Q10	-14.45171	13.85527	-1.04	0.2997	1653741
Q11	14.30167	13.06436	1.09	0.2765	1532836
intq1q8	-0.90947	0.5791	-1.57	0.1198	48789
intq1q10	3.6451	3.46786	1.05	0.296	1848398
intQ1Q11	-4.12725	3.38544	-1.22	0.226	1822263
intq8q10	3.6683	3.60312	1.02	0.3113	2039997
intq8q11	-3.3345	3.48286	-0.96	0.3409	1976725
intQ1Q8Q10	-0.85991	0.86452	-0.99	0.3225	2178549
intQ1Q8Q11	0.98092	0.84749	1.16	0.2501	2156860

The parameter estimate associated with the interaction term intQ8Q11 (interaction term between Q8 and Q11) has the highest p-value among non significant interaction terms. We rerun the model with intQ8Q11 removed. The new model parameter estimates are as provided in Table 6.5 below.

Table 6.5 Linear Regression Estimates with the Interaction Term intQ8Q11 Removed from the Model

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Q1	3.25818	1.7291	1.88	0.0627	23627
Q8	-0.67673	2.20958	-0.31	0.7601	39435
Q10	-1.54093	3.17928	-0.48	0.6291	87154
Q11	2.13222	3.01688	0.71	0.4815	81815
intq1q8	-0.81321	0.57004	-1.43	0.1571	47319
intq1q10	0.60323	1.3891	0.43	0.6651	296849
intQ1Q11	-1.2475	1.55295	-0.8	0.4239	383788
intq8q10	0.2335	0.33356	0.7	0.4857	17499
intQ1Q8Q10	-0.05671	0.20866	-0.27	0.7864	127025
intQ1Q8Q11	0.19868	0.22502	0.88	0.3796	152185

The new non significant parameter estimate for interaction terms with the highest p-value is intQ1Q8Q10 which is the interaction term between Q1, Q8 and Q10. This term is removed from the model. We rerun the model to get the following summary results of parameter estimates in Table 6.6.

Table 6.6 Linear Regression Estimates with the Interaction Term intQ1Q8Q10 Removed from the Model

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Q1	3.0196	1.4823	2.04	0.0445	17538
Q8	-0.41824	1.98448	-0.21	0.8335	32130
Q10	-0.92675	2.22523	-0.42	0.678	43125
Q11	1.4642	1.74078	0.84	0.4024	27514
intq1q8	-0.81086	0.56713	-1.43	0.1561	47308
intq1q10	0.26201	0.59154	0.44	0.6588	54372
intQ1Q11	-0.84654	0.48275	-1.75	0.0828	37459
intq8q10	0.18952	0.29024	0.65	0.5154	13382
intQ1Q8Q11	0.13971	0.05931	2.36	0.0206	10678

The interaction term intQ1Q10 becomes the new term to qualify for elimination from the model on basis of p-value which is the highest among interaction terms with non significant parameter estimates. The model is rerun without intQ1Q10. The resulting parameter estimates have properties summarized in Table 6.7 that follows.

Table 6.7 Linear Regression Estimates with the Interaction Term intQ1Q10 Removed from the Model

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Q1	3.05649	1.4736	2.0700	0.0408	17483
Q8	-1.02756	1.4242	-0.7200	0.4724	16690
Q10	-0.05733	1.0436	-0.0500	0.9563	9568
Q11	0.99522	1.3758	0.7200	0.4713	17335
intq1q8	-0.66876	0.4657	-1.4400	0.1543	32170
intQ1Q11	-0.69645	0.3423	-2.0300	0.0447	19001
intq8q10	0.24288	0.2629	0.9200	0.3580	11077
intQ1Q8Q11	0.12968	0.0546	2.3800	0.0195	9124

Table 6.7 shows that the new interaction term to qualify for elimination from the model is intQ8Q10. Its elimination from the model provides a new model whose parameter estimates are give in Table 6.8.

Table 6.8 Linear Regression Estimates with the Interaction Term intQ8Q10 Removed from the Model

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Q1	2.04340	0.9835	2.08	0.0404	7800
Q8	-0.39774	1.2494	-0.32	0.7509	12865
Q10	0.87371	0.2707	3.23	0.0017	645
Q11	0.36012	1.1908	0.30	0.7630	13006
intq1q8	-0.55943	0.4500	-1.24	0.2169	30092
intQ1Q11	-0.52070	0.2844	-1.83	0.0702	13132
intQ1Q8Q11	0.12484	0.0543	2.30	0.0237	9040

With results in Table 6.8, we need to remove from the model the interaction term intQ1Q8 associated with Q1 and Q8 variables. The model without intQ1Q8 has parameter estimates described in Table 6.9.

Table 6.9 Linear Regression Estimates with the Interaction Term intQ1Q8 Removed from the Model

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Q1	1.12004	0.6465	1.73	0.0864	3351
Q8	-1.72825	0.6463	-2.67	0.0088	3423
Q10	0.81353	0.2671	3.05	0.0030	624
Q11	1.64170	0.5976	2.75	0.0072	3257
intQ1Q11	-0.61216	0.2755	-2.22	0.0286	12253
intQ1Q8Q11	0.07223	0.0341	2.12	0.0367	3545

With interaction term intQ1Q8 eliminated from the model, all the remaining interaction terms (intQ1 and intQ1Q8Q11) have p-value less than 0.05, the statistical significance level. However, with these two terms still in the model, the parameter estimate for Q1 is not significant. We therefore remove the interaction term with the highest p-value and check if the model and its parameter estimates are significant. We remove intQ1Q8Q11which has the highest p-value among the two interaction terms. Summary results for the new model's parameter estimates are shown in Table 6.10.

Table 6.10 Linear Regression Estimates with the Interaction Term intQ1Q8 Removed from the Model

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Q1	-0.17056	0.2199	-0.78	0.4399	374
Q8	-0.42172	0.1964	-2.15	0.0343	305
Q10	0.85262	0.2712	3.14	0.0022	621
Q11	0.44534	0.1989	2.24	0.0274	348
intQ1Q11	-0.03291	0.0340	-0.97	0.3348	180

We observe from Table 6.10 above that the parameter estimate associated with the interaction term intQ1Q11 is not significant. This interaction is removed from the model. Parameter estimates for the model without any of interaction terms is the same model described in section 6.2.2. The summary statistics for parameter estimates are as provided in Table 6.1.

We conclude that no interaction term for the four variables already in the model (Q1, Q8, Q10 and Q11) qualifies to be added into the model.

6.2.4 Variable Transformations

In an attempt to stabilize the variance of residuals and parameter estimates, we carry out variable transformation. We use the log of grade_avg as the new dependent variable and in addition the SEF variables Q1 to Q17, we take square, cube and log transformations of the SEFs as the new independent variables. The model is built using the stepwise selection of variables with p-value equal to 0.05.

Table 6.11 below provides a summary on parameter estimates. The model retains Q3, CubQ9, CubQ10, CubQ11, LogQ4, and LogQ7 variables. All parameter estimates are significant. Variance inflation factors are below 10 which is good. As it can been seen from Table 6.12, the highest condition index is about 97 (less than 100) which means that there is a moderate multicollinearity problem which is not a serious issue. Appendix L contains the SAS Output for the model with variable transformations.

We recall that condition indices for the matrix $X'X$ are defined as $C_j = \frac{\lambda_{max}}{\lambda_j}$, where λ_j is the j^{th} eigenvalue of the matrix $X'X$ and j=1, 2, …, p.

A large C_j implies that λ_j is relatively small compared to the maximum observed eigenvalue for $X'X$. This indicates a situation of near-linear dependence in the observed data.

The model formula is:

$$\boxed{Logy = 1.69131 + 0.44930 * Q3 - 0.00672 * CubQ9 + 0.00730 * CubQ10 + 0.00413 * CubQ11 - 1.63290 * LogQ4 - 0.55153 * LogQ7},$$

where Logy is the Log of grade_avg (the course grade average per student), Q3 is the course average rating for “Faculty member gave assignments related to the goals of this course”, CubQ9 is the cube of course average rating to Q9 (Faculty member had designated office and student appointment hours and was available to students during these times), CubQ10 is the cube for the course average rating to Q10 (Faculty member assigned grades fairly), CubQ11 is the cube for the course average rating to Q11 (Faculty member returned test results and evaluations of my work in a reasonable period of time), LogQ4 is the log for the course average rating to Q4 (Faculty member followed the plan for the course as established in the syllabus), and logQ7 is the log for the course average rating to Q7 (Faculty member responded constructively and thoughtfully to questions and comments).

Parameter estimates for Q3, CubQ10, and CubQ11 have a positive signs which means that these variables are positively correlated with Logy. The signs for CubQ9, LogQ4 and LogQ7 are negative which indicates that they are negatively correlated with Logy. The formula to get the predicted values of course average grade per student is as follows:

$$\boxed{pred\_grade\_avg = e^{(1.69131 + 0.44930 * Q3 - 0.00672 * CubQ9 + 0.00730 * CubQ10 + 0.00413 * CubQ11 - 1.63290 * LogQ4 - 0.55153 * LogQ7)}}$$

Table 6.11 Linear Regression Parameter Estimates with the Variable Transformations

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Intercept	1.69131	0.34445	4.91	<.0001	0.00
Q3	0.44930	0.10693	4.20	<.0001	8.06
CubQ9	-0.00672	0.00166	-4.06	0.0001	4.61
CubQ10	0.00730	0.00190	3.83	0.0002	5.73
CubQ11	0.00413	0.00162	2.55	0.0123	3.90
LogQ4	-1.63290	0.37112	-4.40	<.0001	5.49
LogQ7	-0.55153	0.19397	-2.84	0.0055	4.03

Table 6.12 Collinearity Diagnosis for the Model with Variable Transformations

Number	Eigenvalue	Condition Index
1	6.90684	1.00000
2	0.06103	10.63785
3	0.01508	21.40105
4	0.01068	25.43105
5	0.00414	40.85658
6	0.00149	68.12190
7	0.00073867	96.69758

6.2.5 Analysis of Adequacy for the Model with Variable Transformations

Figure 6.1 below gives the histogram of the residual distribution. It can be seen that the histogram has a near bell-shaped form. This enables us to conclude that prediction errors are approximately normally distributed. The plot of normal probabilities in Figure 6.2 is close to the diagonal line. This confirms that we have no evidence of violation of the normal assumption about error distributions.

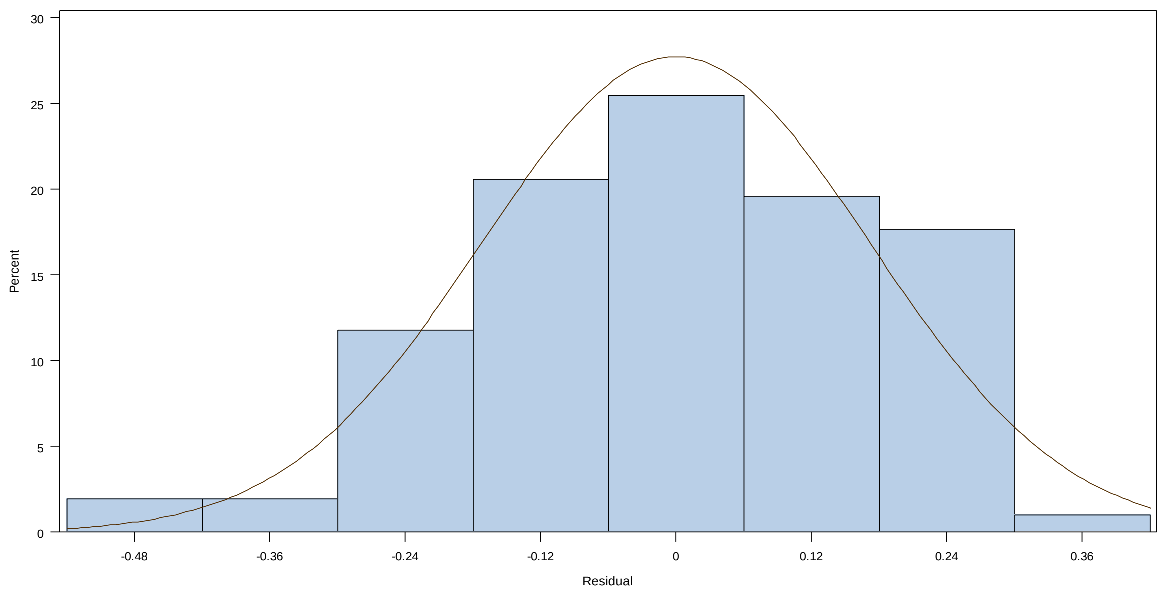


Figure 6.1 Distribution of Residuals for the Model with Variable Transformations

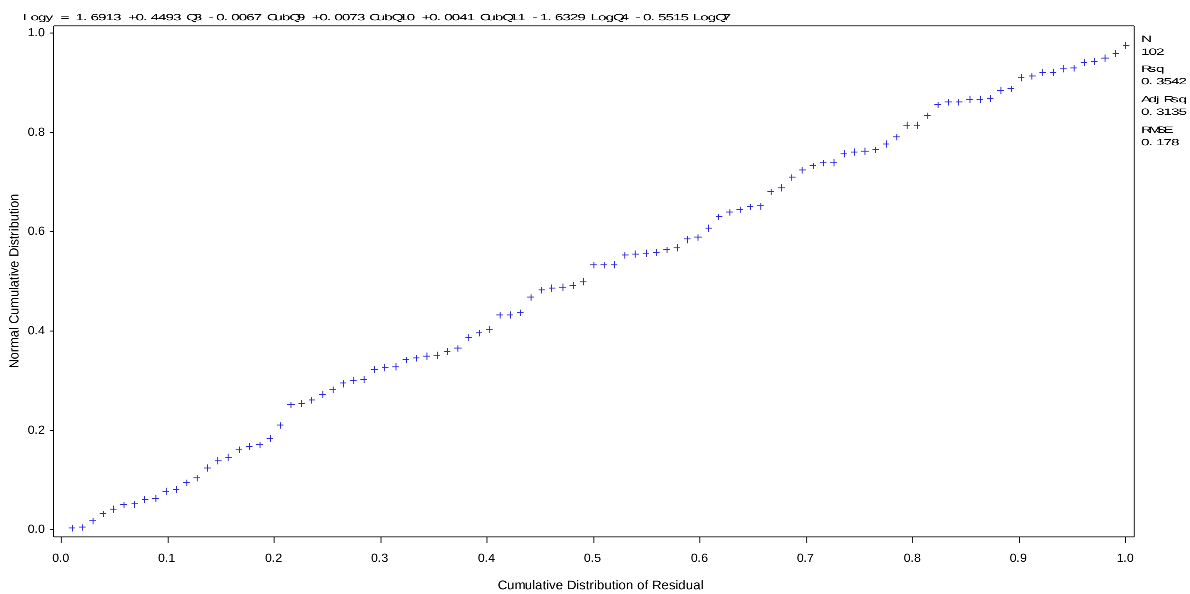


Figure 6.2 Normal Probability Plot for the Model with Variable Transformations

We continue with residual analysis to check the model adequacy by studying plots of residuals against the individual predictors. The shape of these plots provide a good indication about the variances for residuals. We need to verify if there is no violation of the linear regression assumption of constant variance for errors.

Figures 6.3 to 6.9 provide the plot of residuals against predicted values and against predictor Q3, CubQ9, CubQ10, CubQ11, LogQ4, and LogQ7, respectively. The figures reveal some departure from the constant variance assumption since we see that residual amplitudes tend to increase or decrease. In the next section we try to validate the model with validation sample data.

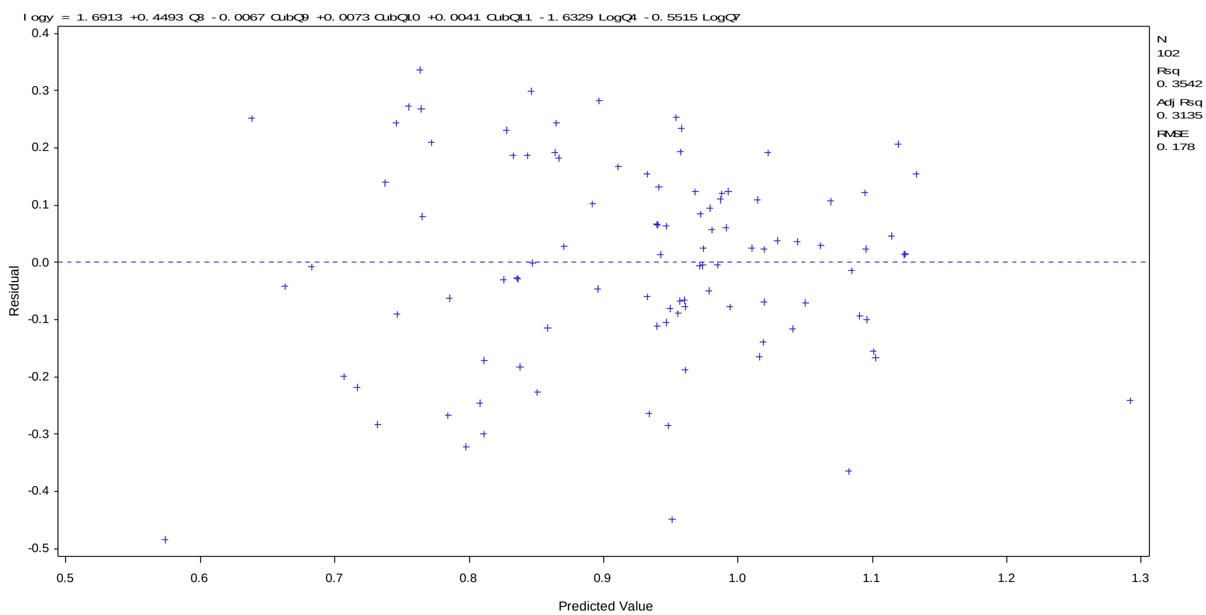


Figure 6.3 Plot of Residuals versus Predicted Values for the Model with Variable Transformations

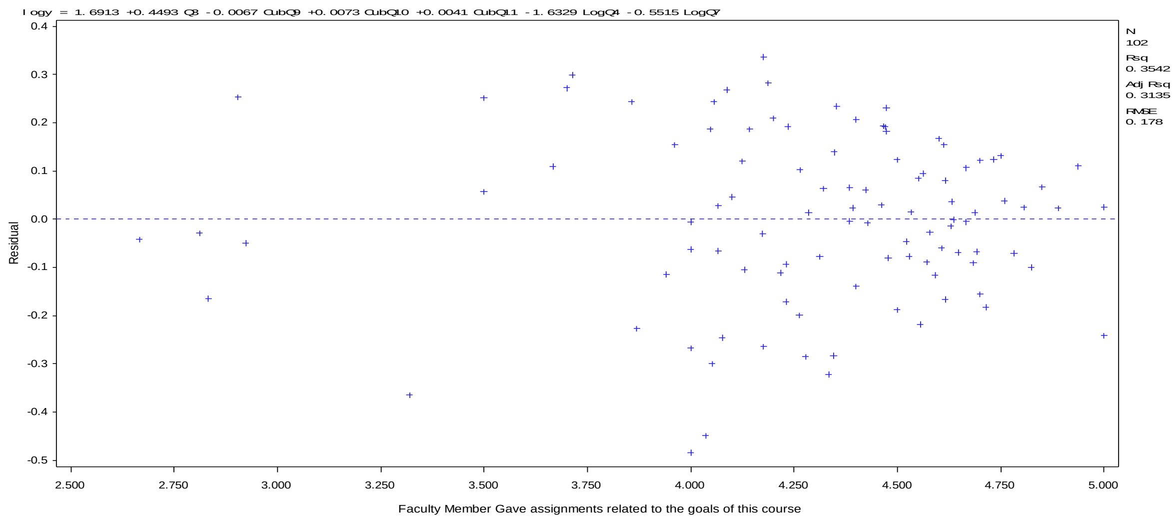


Figure 6.4 Plot of Residuals versus Q3 (Faculty member gave assignments related to the goals of this course)

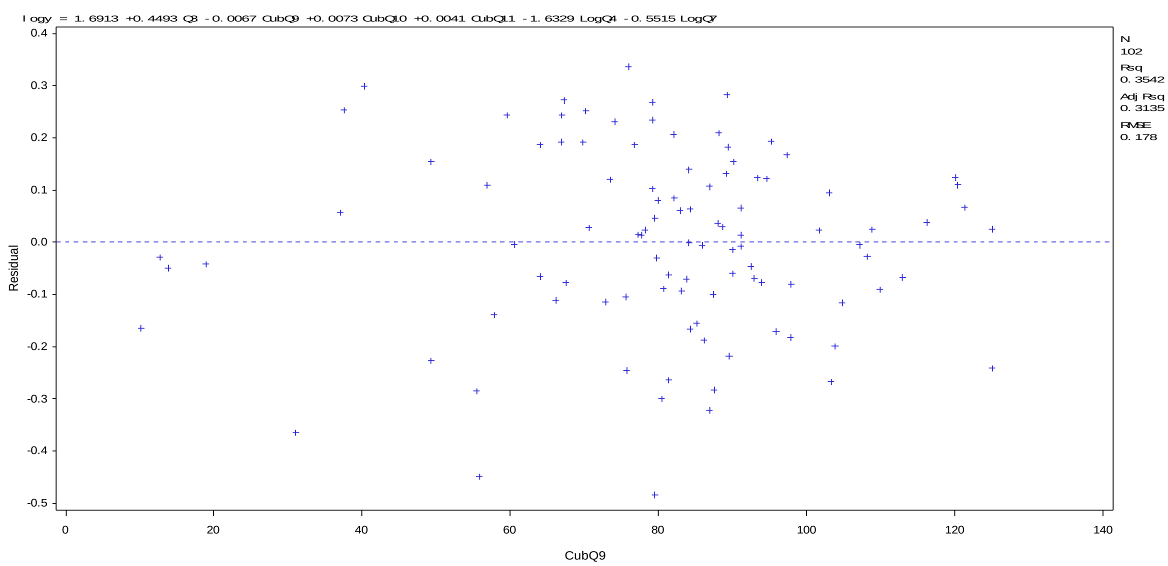


Figure 6.5 Plot of Residuals versus CubQ9 (Cube of Q9, Faculty member had designated office and student appointment hours and was available to students during these times)

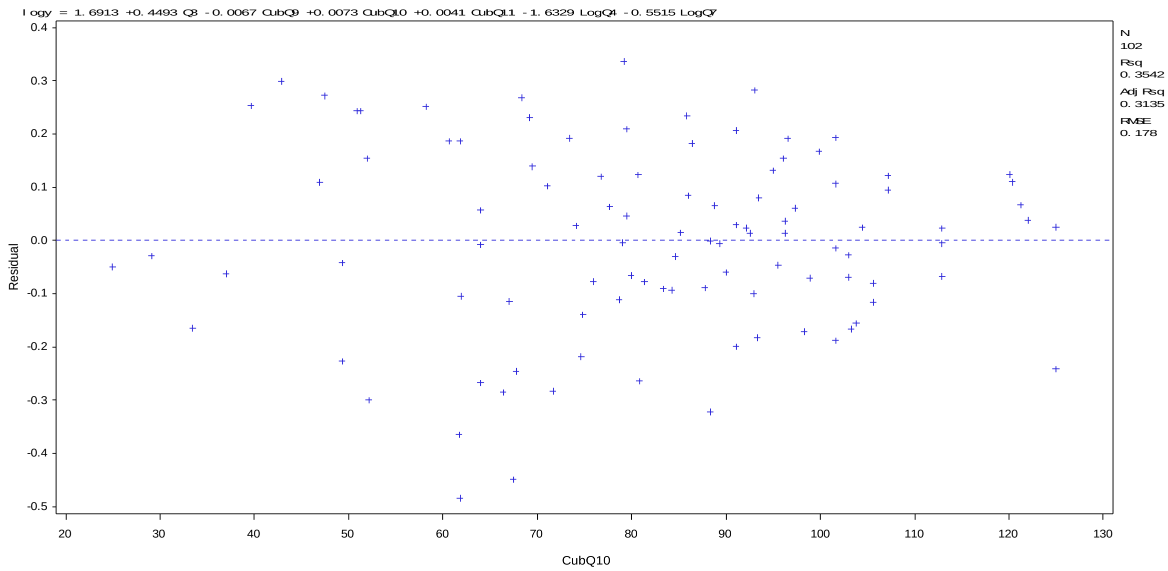


Figure 6.6 Plot of Residuals against CubQ10 (Cube of Q10, Faculty member spoke in a way that communicated the subject in an understandable manner)

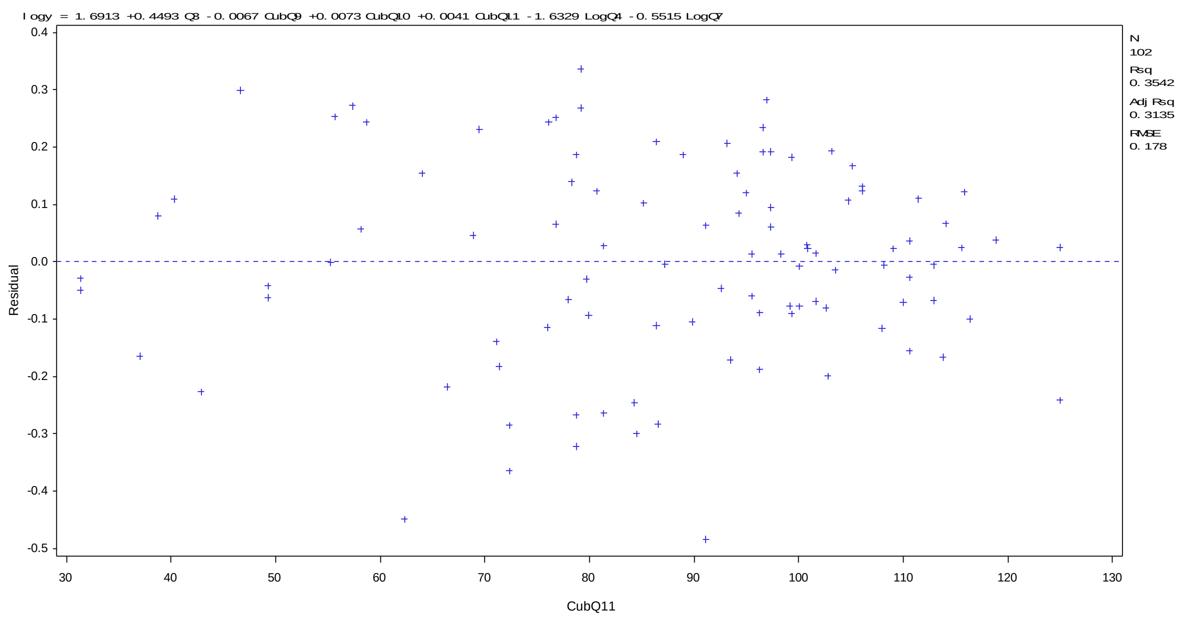


Figure 6.7 Plot of Residuals against CubQ11 (Cubic of Q11, Faculty member returned test results and evaluations of my work in a reasonable period of time)

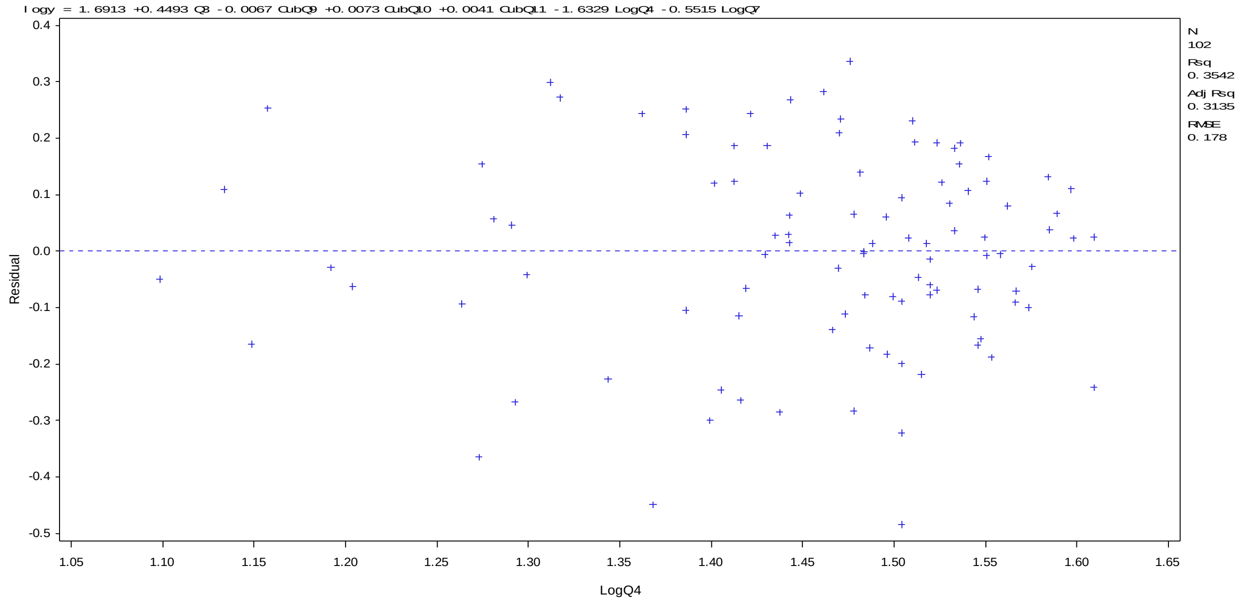


Figure 6.8 Plot of Residuals against LogQ4 (Log of Q4, Faculty Member Followed the plan for the course as established in the syllabus)

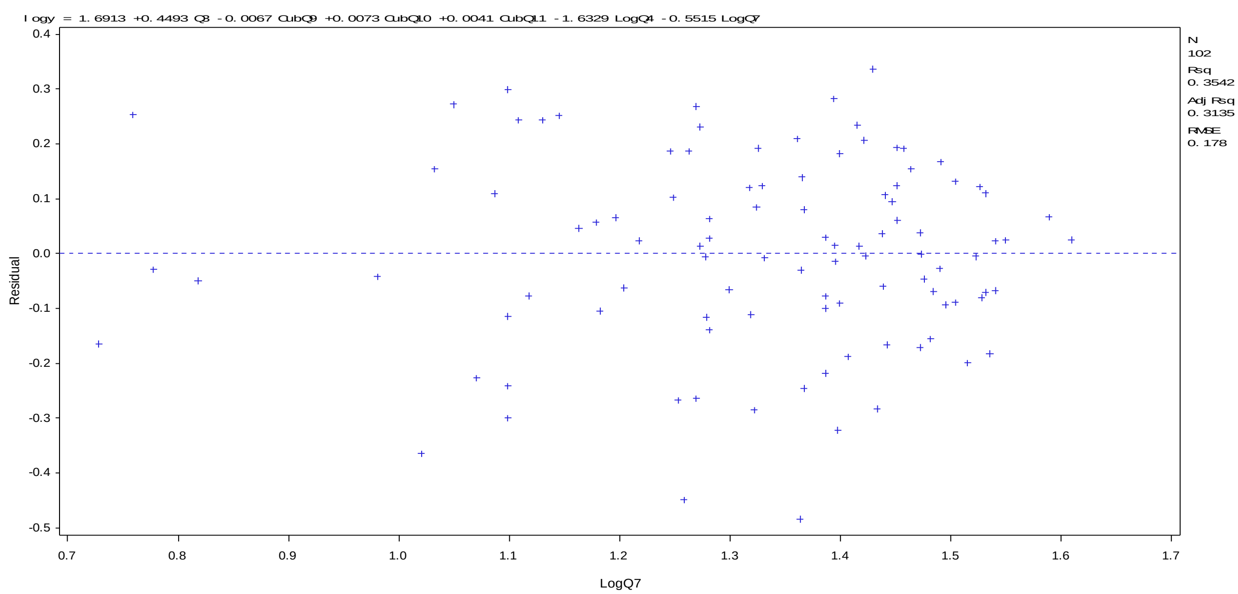


Figure 6.9 Plot of Residuals against LogQ7 (Log of Q7, Faculty Member Responded constructively and thoughtfully to questions and comments)

6.2.6 Validation of the Model with Variable Transformations Using Validation Sample

We apply to the validation sample data the formula already defined above for predicted faculty performance (course grade average per student). The formula is:

$$pred\_grade\_avg = e^{(1.69131 + 0.44930 * Q3 - 0.00672 * CubQ9 + 0.00730 * CubQ10 + 0.00413 * CubQ11 - 1.63290 * LogQ4 - 0.55153 * LogQ7)}$$

A good fit of predicted values to the observed values would provide strong evidence about the model adequacy. The computed predicted values and related residuals for the validation sample are in Appendix M. Figure 6.10 below shows how the predicted values fit observed course grade averages.

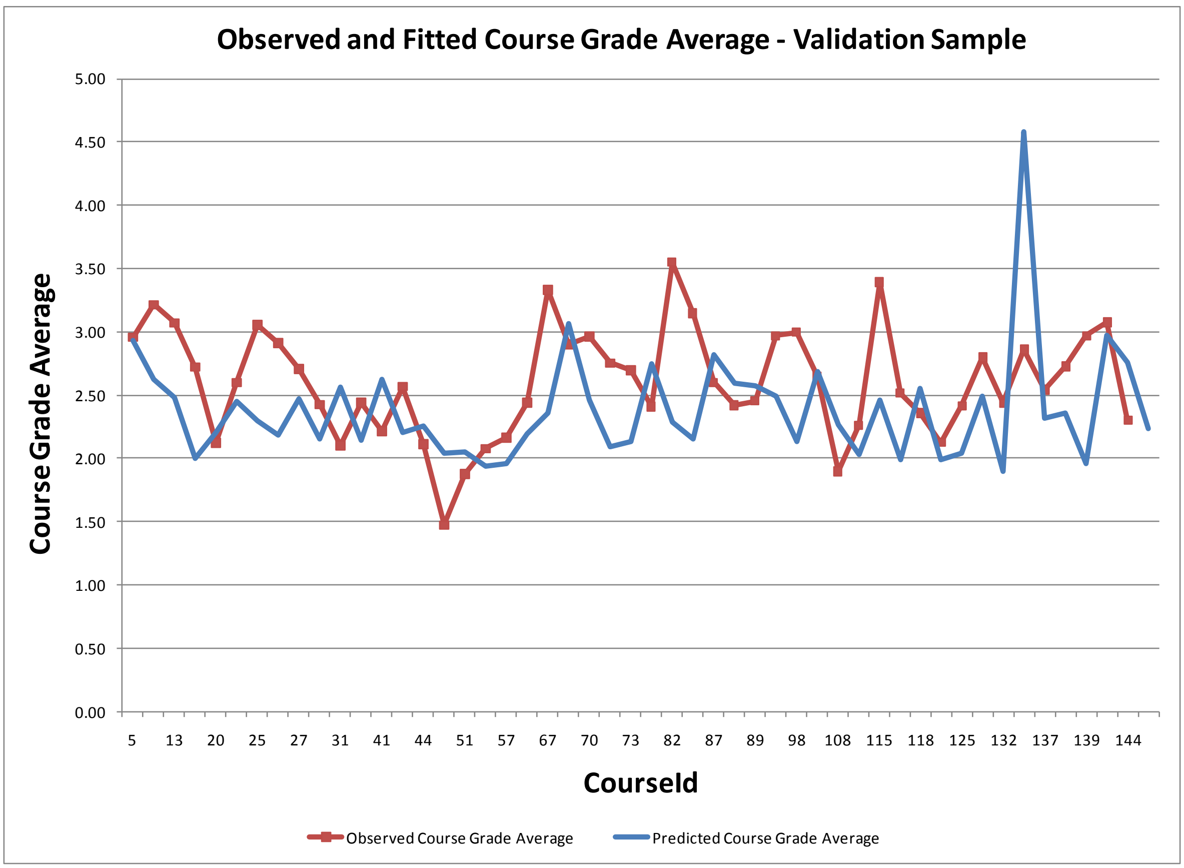


Figure 6.10 Observed and Fitted Values for the Validation Sample with Variable Transformations

The two series have similar trend. However comparison of individual observations shows that the fitting of observed course grade average by the model predicted grade average value is not adequate. One course appears to have extreme predicted value (coursed=135).

Figure 6.12 reveals that the variation of residuals is high. This confirms what we already saw with the model residual analysis. With the violation of the constant variance assumption, this kind of situation is not surprising. We conclude that the model with variable transformations fails to provide a good fit for the faculty performance as measured by course grade average per student.

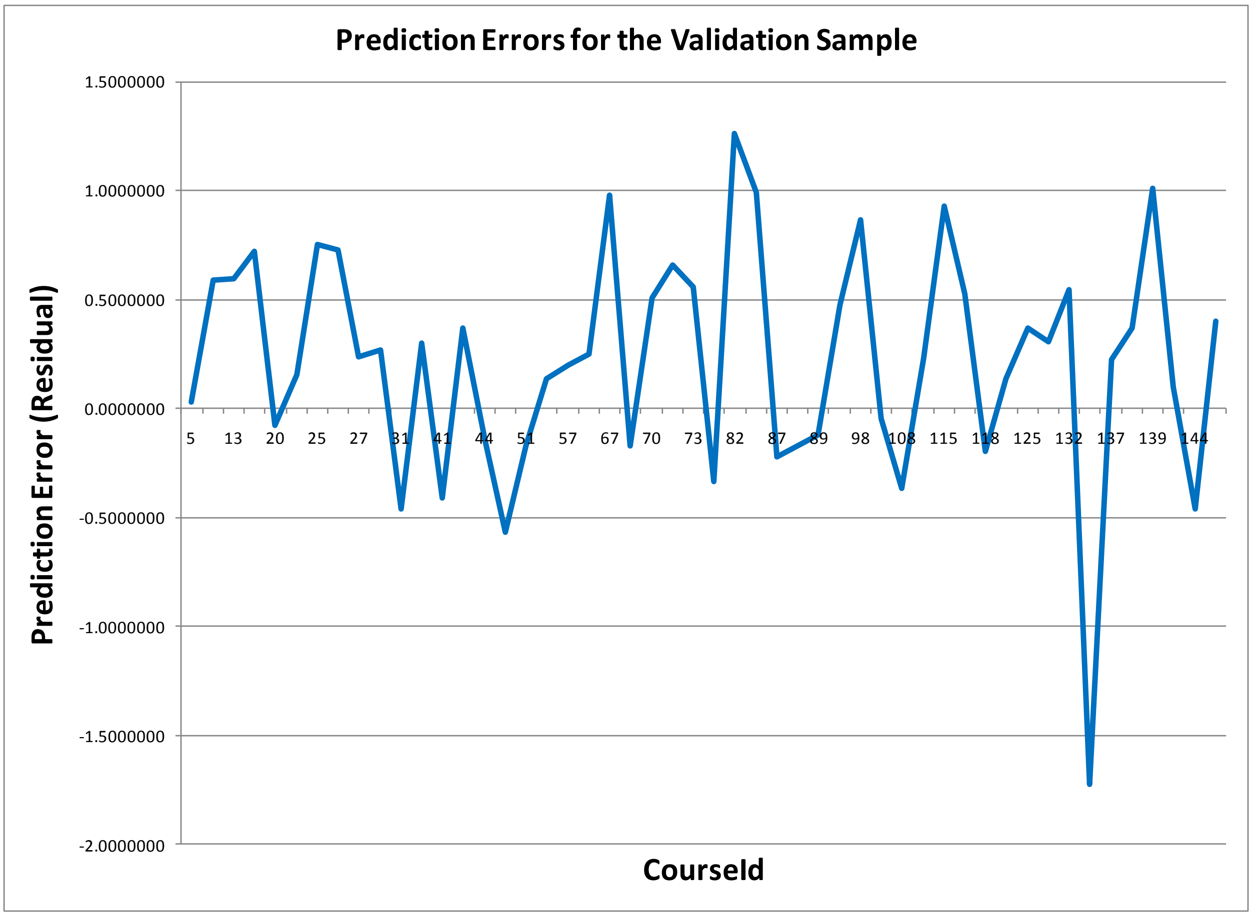


Figure 6.11 Plot of Prediction Errors against CourseID for the Validation Sample with Variable Transformations.

Chapter 7

LOGISTIC REGRESSION MODEL

7.1 Review of the Method

Logistic Regression is a special case of Generalized Linear Model (GLM). In regression analysis, GLM is a set of methods used to fit regression models when the assumptions of normally distributed response variable with constant variance are not verified. The use of GLM constitutes an alternative to linear regression if variable transformations do not provide a good fitting model. The response variable must be a member of the exponential family that include normal, Poisson, binomial, gamma, and exponential distributions.

Logistic regression is appropriate when the response variable has only two possible outcomes, 1 for success and 0 for failure to observe an event. The success or failure of an event can be attributed to a number of factors called predictors which can be numerical or categorical.

Let us consider a response variable that is binomially distributed. $Y_i \sim B(n_i, p_i)$, for i=1, 2, ..., N, and n_i are known and equal to the numbers of Bernoulli trials and p_i are the unknown probabilities of success. For each trial i, the probability of success is modeled as $p_i = E\left(\frac{Y_i}{n_i} \middle| X_i\right)$. The corresponding odds $o_i = \frac{p_i}{1-p_i}$.

The natural logs of the odds called logits are modeled as follows:

$\text{logit}(p_i) = \ln\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 \mathrm{x}_{1\mathrm{i}} + \beta_2 \mathrm{x}_{2\mathrm{i}} + \ldots + \beta_\mathrm{k} \mathrm{x}_{\mathrm{ki}}$, where the parameters β_j are usually estimated by the method of maximum likelihood.

This is equivalent to modeling the unknown p_i as $p_i = \frac{e^{(\beta_0 + \beta_1 \mathrm{x}_{1\mathrm{i}} + \beta_2 \mathrm{x}_{2\mathrm{i}} + \ldots + \beta_\mathrm{k} \mathrm{x}_{\mathrm{ki}})}}{1 + e^{(\beta_0 + \beta_1 \mathrm{x}_{1\mathrm{i}} + \beta_2 \mathrm{x}_{2\mathrm{i}} + \ldots + \beta_\mathrm{k} \mathrm{x}_{\mathrm{ki}})}}$.

It can also be written under this form: $p_i = \frac{1}{1 + e^{-(\beta_0 + \beta_1 \mathrm{x}_{1\mathrm{i}} + \beta_2 \mathrm{x}_{2\mathrm{i}} + \ldots + \beta_\mathrm{k} \mathrm{x}_{\mathrm{ki}})}}$

7.2 Application of the Method

We recall that in chapter 6 we attempted to build a linear regression model without success. All the models we tried to build violated at least one of the assumptions of ordinary least squares. We now attempt to build a logistic model.

7.2.1 Model formulation

For each course i, we know the number of students that get a given grade level (Aplus, A, Aminus, Bplus, B, Bminus, Cplus, C, Cminus, D, and F). We define the new response variable Y_i as the indicator of the proportion of high performing students (percent of student with a grade B or higher) greater or equal than 0.40 . Let hperf be the proportion of students with a grade of B or higher. If hperf is greater or equal to 0.40 than Y_i $=1$, else Y_i = 0. In other words, for each course i, Y_i $=1$ means that the performance of the related faculty member is high (i.e. hperf=1 is SAS code). Inversely, Y_i $=0$ means that the faculty performance is low (hperf=0). Thus, with this formulation, the derived logistic regression model would enable us to predict faculty performance on the basis of student evaluation of faculty which will be expressed by scores generated by the model.

The SAS code for the definition of the new response variable and the development of the logistic model is in Appendix P. The SAS proc logistic is used to build the model.

7.2.2 The Logistic Model Formula

Table 7.1 below provides the estimates of the regression model parameters. Of the 18 potential predictors (Q1 to Q17, and math – the math class level indicator), only four are kept into the model, namely Q9 (Faculty Member Had designated office and student appointment hours and was available to students during these times), Q11 (Faculty Member Returned test results and evaluations of my work in a reasonable period of time), Q16 (Faculty Member Assigned readings, including the texts, that contributed to what I learned), and math (the indicator for the math course level, equals 1 if the course section is one of 2008, 2211, 2212, 2215 or 2420, and takes the value 0 if not).

Table 7.1 Logistic Model Parameter Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-7.1988	3.1392	5.2587	0.0218
Q9	1	-2.1322	0.9626	4.9060	0.0268
Q11	1	2.7178	1.1402	5.6812	0.0171
Q16	1	1.8425	0.7856	5.5007	0.0190
math	1	-4.0660	0.9286	19.1708	<.0001

The parameter estimates for predictor Q9, Q11, Q16, and math are significant. The proportion of concordant predicted probabilities and observed responses is 89.2% as revealed by Table 7.2 below.

The model: $p = \dfrac{1}{1+e^{-(-7.1988-2.1322Q9+2.7178Q11+1.8425Q16-4.0660math)}}$ or

$\boxed{p = \dfrac{1}{1+e^{(7.1988+2.1322Q9\ -\ 2.7178Q11\ -1.8425Q16\ +4.0660math\ )}}}$, where p is the predicted probability for the event that the faculty member has high performance.

Table 7.2 Association of Predicted Probabilities and Observed Responses

Percent Concordant	89.2	Somers' D	0.784
Percent Discordant	10.8	Gamma	0.785
Percent Tied	0.1	Tau-a	0.259
Pairs	1701	c	0.892

7.2.3 The Model Accuracy

We test the model accuracy by requesting the SAS proc logistic to provide a measure of the model goodness-of-fit which is achieved with the output of the Hosmer-Lemeshow Goodness-of-Fit test statistic. The Hosmer-Lemeshow Goodness-of-Fit test statistic is provided by the formula:

$H = \sum_{1}^{m} \dfrac{(O_g - E_g)^2}{N_g \pi_g (1-\pi_g)}$, where O_g , E_g , N_g , and π_g are the observed events, expected events, number of observations, and predicted probability for faculty high performance (predicted risk) for the g^{th} faculty performance decile group. The Chi-Square (with 8 DF) = 13.4817 and the corresponding pvalue (Pr > ChiSq) is 0.0963 which would be acceptable at the significance level of 0.10. Hence, based on the development sample used to build the model, the logistic model is accurate at the significance level of 0.10.

The SAS output also provides a classification table (Table 7.3) with cut-off probabilities and statistics about correct and incorrect predictions of high faculty performance. Table 7.3 shows that with a cut-off probability of 0.40, 86.3 percent of faculty members are correctly classified either as high performing or low performing. The corresponding sensitivity rate (the proportion of actual high performing faculty members identified as such by the model classification) is about 96.3% which is high.

Table 7.3 Classification Table for Correct and Incorrect Predictions of High Faculty Performance.

	Correct		Incorrect		Percentages				
Prob Level	Event	Non-Event	Event	Non-Event	Correct	Sensi-tivity	Speci-ficity	False POS	False NEG
0.200	81	6	15	0	85.3	100.0	28.6	15.6	0.0
0.300	80	8	13	1	86.3	98.8	38.1	14.0	11.1
0.400	78	10	11	3	86.3	96.3	47.6	12.4	23.1
0.500	74	12	9	7	84.3	91.4	57.1	10.8	36.8
0.600	71	12	9	10	81.4	87.7	57.1	11.3	45.5
0.700	67	14	7	14	79.4	82.7	66.7	9.5	50.0
0.800	63	15	6	18	76.5	77.8	71.4	8.7	54.5

7.2.3 The Model Validation with the Validation/Holdout Sample

We further validate the model accuracy by scoring the validation sample and computing for each faculty member (or each course), the predicted probability of high performance. Then using the cut-off value of 0.4 for predicted probability of high performance, we derive the proportion of observations correctly classified by the model as high performing faculty member or correctly classified as low performing faculty member, and the achieved sensitivity rate in the validation sample. Table 7.4 below provides the summary results of applying the model to the holdout sample.

Out of a total of 50 observations in the validation sample, 35 are actually classified as high performance while 15 are actually classified as low performance. The predicted high performance observations are 42 against 8 low performance observations. 32 high performance observations are correctly predicted while 5 low performance observations are correctly predicted. This leads to a proportion of correctly predicted observations of about 74.0%. The sensitivity rate is about 91.4%, which indicates that 91.4% of faculty members in the validation sample actually identified as "high performance" are truly classified by the predictive model as "high performance".

Table 7.4 Actual versus Predicted High Performance Faculty in the Validation Sample

		Predicted High Performance Indicator		Total
		0	1	
Actual High Performance Indicator	0	5	10	15
	1	3	32	35
Total		8	42	50

7.3 Scoring the Whole Sample

The entire sample is scored using the model built with data in the development sample. The summary results are presented in table 7.5 below. The corresponding proportion of correctly predicted observations is about 84.2%. The sensitivity rate is about 96.6%, which means that 96.6% of faculty members in the whole sample actually identified as “high performance” are truly classified by the predictive model as “high performance” . This indicates a high predictive ability of the logistic regression model in classifying the faculty members according to their high performance.

The table with actual proportion of high performance (hperf) and the corresponding predicted probability of high performance (Score) for each course are in Appendix N.

Table 7.5 Actual versus Predicted High Performance Faculty in the Whole Sample

		Predicted High Performance Indicator		
		0	1	Total
Actual High Performance Indicator	0	16	20	36
	1	4	112	116
Total		20	132	152

Chapter 8

DISCUSSIONS AND CONCLUSION

8.1 Summary Results

We recall that several methods were applied in our search for a possible suitable model to study the relationship that may exist between Faculty Performance (expressed in terms of Course Grade Average per Student) and Student Evaluation of Faculty (SEF) as measured by average students' ratings of faculty member and eventually predict faculty performance on basis of SEFs. The methods tried include Principal Components, Pearson's Correlation, Spearman's Rank Correlation, Kendall's Rank Correlation, Linear Regression Models, and Logistic Regression Models.

The analysis of correlations revealed no evidence of strong relationship between Faculty Performance measured by course grade average and Student Evaluation of Faculty. With respect to Linear Regression, several models were tried to regress course grade average against the average SEFs and their interaction terms. The analysis of residuals and the model validation with the validation sample showed that these models were not adequate. We consistently observed a problem of heteroscedasticity with each model tried. As a way for variance stabilization, we attempted to fit a model with transformation of the dependent variable using log function and transformation of independent variables using square, cube and log transformations. The resulting model did not fit faculty performance in an adequate manner.

It is possible that some confounding factors may be present in the data that affect or bias the prediction of faculty performance on basis of students' ratings of faculty members. As we pointed out in the introduction, this phenomenon of bias is often observed. Such bias can easily affect the stability of parameter estimates and the violation of the assumption of constant error variances.

The logistic regression model presented in chapter 7 enables us to predict faculty high performance with an acceptable level of accuracy. Faculty high performance is defined as the proportion of students that get a grade B or higher. The logistic model is as follows: $\boxed{p = \frac{1}{1+e^{(7.1988+2.1322\mathrm{Q9}\ -\ 2.7178\mathrm{Q11}\ -1.8425\mathrm{Q16}\ +4.0660\mathrm{math}\ )}}}$, where p is the predicted probability for the event that faculty member has high performance, Q9, Q11, and Q16 are average student ratings of the faculty on "Faculty Member Had designated office and student appointment hours and was available to students during these times", "Faculty Member Returned test results and evaluations of my work in a reasonable period of time", and "Faculty Member Assigned readings, including the texts, that contributed to what I learned", respectively, while math is the indicator for course level.

8.2 Recommended Model and Implementation

We recommend the use of the logistic model defined above to predict the probability that a faculty member has "high performance" given average student ratings of the faculty for statement Q9, Q11 and Q16 defined above, and the indicator of the course section (math) for the math class.

Recommended Model: $\boxed{p = \frac{1}{1+e^{(7.1988+2.1322\mathrm{Q9}\ -\ 2.7178\mathrm{Q11}\ -1.8425\mathrm{Q16}\ +4.0660\mathrm{math}\ )}}}$.

The model implementation implies getting for each of the concerned faculty members the values for Q9, Q11, and Q16 as defined above, then give the variable math the value of 1 if the course thought is in course sections 2008, 2211, 2212, 2215 or 2420, and otherwise give math the value 0. Once this done, apply the model formula above to obtain the predicted probability p of high performance faculty, then use the cut-off value of 0.4 to classify the faculty member as “high performance” (hp=1) if p greater or equal to 0.4 or as “low performance” (hp=0) if p less than 0.4. The logistic regression model can also be used to score and compare faculty members’ performance using their scored/predicted probabilities of high performance as shown in Appendix N.

8.3 Future Work

Future studies on this subject may try to use detailed data at student level (namely each student’s grade in the course and each student’s ratings of the related faculty member), analyze and isolate any potential confounding factors in students’ ratings of faculty members, and fit logistic regression model for the prediction of Faculty Performance. The use of detailed data and consideration of confounding factors to student evaluation of faculty would improve the accuracy of the predictive model.

Potential confounding factors include: anonymity of rating students, time of rating (whether rating is carried out before or after students have received a feedback of their performance in the course), student motivation, learning effectiveness (students who learn more usually get high grades), effect of expected versus received grades (students receiving less than expected grade tend to provide unfavorable ratings to related faculty members), difficulty of the course taught which can lead students in providing biased ratings to faculty teaching effectiveness, and student enrollment type in the course (whether the course is required or is an elective one).

REFERENCES

[1] Feldman, K. A., Grades and college students' evaluations of their courses and teachers, *Research in Higher Education*, Vol. 4, pp. 69-111, 1976.

[2] Feldman, K. A., The significance of circumstances for college students' ratings of their teachers and courses, Research in Higher Education, Vol. 10, pp. 149-172, 1979.

[3] Fraser, C., and Bradford, J. W., Competitive Market Structure Analysis: Principal Partitioning of Revealed Substitutabilities, *The Journal of Consumer Research*, Vol. 10, No. 1, pp. 15-30, 1983.

[4] Hunter, M. A., and Yoshio, T., Constrained Principal Component Analysis:Various Applications, *Journal of Educational and Behavioral Statistics*, Vol. 27, No. 2, pp. 105-145, 2002.

[5] Khattree, R., and Naik, D. N., Applied Multivariate Statistics, *2nd Edition, SAS Institute Inc.*, 1999.

[6] Lagona, F., and Fabio Padovano, F., A Nonlinear Principal Component Analysis of the Relationship between Budget Rules and Fiscal Performance in the European Union, *Public Choice*, Vol. 130, No. 3/4, pp. 401-436, 2007.

[7] Leng, C., and Wang, H., On General Adaptive Sparse Principal Component Analysis, *Journal of Computational and Graphical Statistics*, Volume 18, Number 1, 201–215, 2009.

[8] Lin, L. I-K., A Concordance Correlation Coefficient to Evaluate Reproducibility, *International Biometric Society*, Vol. 45, pp. 255-268, 1989.

[9] Little, R. C., Milliken, G. A., Stroup, W. W., and Wolfinger, R. D., Schabenberger, O., SAS for Mixed Model, 2nd Edition, *SAS Press*, 2006.

[10] Manatunga, A., Assessing Agreement between Ordinal and Continuous Measurements, Department of Biostatistics and Bioinformatics, Rollins School of Public Health, Emory University, 2011.

[11] Martin, D., and Kumar, V., Detecting outliers and influential observations with heteroscedasticity-corrected models, *Applied Economics Letters*, Vol. 12, pp.745–748, 2005.

[12] Montgomery, D. C., Peck, E. A., and Vining, G. G., Introduction to Linear Regression Analysis, *4th Edition, John Wiles & Sons, Inc.*, 2006.

[13] Nimmer, J. G., and Stone, E. F., Effects Of Grading Practices And Time Of Rating On Student Ratings Of Faculty Performance And Student Learning, *Research in Higher Education*, Vol. 32, No 2, 195-215, 1991.

[14] Park, J., and Basawa, I. V., Optimal Estimating Equations for Mixed Effects Models with Dependent Observations, *Institute of Mathematical Statistics,* Lecture Notes-Monograph Series, Vol. 37, pp. 247-268, 2001.

[15] Sen, P. K., Estimates of the regression coefficient based on Kendall's tau, *Journal of the American Statistical Association*, Vol. 63, pp. 1379-1389, 1968.

[16] Stone, E. F., Spool, M. D., and Rabinowitz, S., Effects Of Anonymity And Retaliatory Potential On Student Evaluations Of Faculty Performance, *Research in Higher Education*, Vol. 6, pp 313-325, 1977.

APPENDICES

Appendix A: Sample Data for Grade Distribution by Course

courseid	Aplus	A	Aminus	Bplus	B	Bminus	Cplus	C	Cminus	D	F	I	S	U	AU	W	WF	OTH	grade_avg
17830101	2	5	3	3	4	2	1	0	0	1	2	0	0	0	0	2	0	0	2.7
17910101	1	2	7	4	1	2	1	3	0	1	1	0	0	0	0	1	0	0	2.7
17910201	0	0	1	3	3	3	1	6	0	1	2	0	0	0	0	2	0	0	2.4
17720801	1	11	6	6	4	5	2	6	0	0	2	0	0	0	0	5	0	0	2.8
17720901	1	2	2	1	3	2	3	3	0	5	3	0	0	0	0	1	0	0	2.2
17830102	8	3	0	4	2	3	2	8	0	2	5	0	0	0	0	6	0	1	2.6
17910102	1	2	2	2	2	1	0	7	0	2	1	0	0	0	0	1	0	0	2.5
17720802	10	6	2	2	0	4	0	5	0	4	3	0	0	0	0	11	0	0	2.8
17720902	3	3	5	5	7	4	1	4	0	4	1	0	0	0	0	6	0	0	2.7
17910103	0	1	2	3	3	2	2	6	0	3	4	0	0	0	0	0	0	0	2.2
17720803	6	4	4	2	7	6	1	4	0	2	2	0	0	0	0	8	0	0	2.8
17820803	3	4	4	10	6	5	3	1	0	5	0	0	0	0	0	5	0	0	2.8
17720903	2	3	6	3	8	5	2	5	0	3	5	0	0	0	0	4	0	0	2.4
17921203	2	3	5	4	6	1	0	2	0	5	9	0	0	0	0	6	0	0	2.0
17720904	0	1	3	3	2	0	2	5	0	3	4	0	0	0	0	4	0	0	2.1
17750904	4	6	10	8	2	4	1	4	0	1	2	0	0	0	0	5	0	0	2.8
17851204	6	5	4	6	6	2	3	4	0	3	2	0	0	0	0	5	0	0	2.7
17910105	0	1	2	1	3	2	1	4	0	2	1	0	0	0	0	4	1	0	2.4
17720805	0	1	2	3	5	1	1	3	2	1	0	0	0	0	0	0	0	0	2.6
17750905	4	5	8	5	2	1	2	7	0	2	5	0	0	0	0	7	0	0	2.5
17851205	0	0	1	2	2	2	4	1	0	4	6	0	0	0	0	0	0	0	1.8
17770306	4	7	7	1	6	2	4	4	0	3	4	0	0	0	0	5	0	0	2.6
17870506	0	5	3	3	3	0	1	4	0	2	2	0	0	0	0	0	0	0	2.5
17720806	7	5	4	5	4	6	1	4	0	3	5	0	0	0	0	3	0	0	2.6
17750906	10	7	2	7	6	3	5	2	0	0	2	2	0	0	0	1	0	0	3.0
17851206	1	1	4	2	7	3	4	7	0	4	11	0	0	0	0	1	0	0	2.0
17910107	3	0	4	4	5	1	1	4	0	0	1	0	0	0	0	0	0	0	2.8
17760307	0	2	3	7	2	3	1	5	0	1	0	0	0	0	0	0	0	0	2.7
17870507	1	2	0	1	3	3	2	4	0	1	5	0	0	0	0	1	0	0	2.1
17910607	2	2	2	1	4	2	1	3	0	2	3	0	0	0	0	1	0	0	2.4
17720807	5	3	3	6	1	2	1	12	0	5	5	0	0	0	0	2	0	0	2.4
17720907	2	2	1	2	1	2	0	4	0	5	11	0	0	0	1	13	1	0	1.6
17851207	0	3	0	0	5	1	2	7	0	3	1	0	0	0	0	0	0	0	2.4
17910108	2	3	0	2	3	2	0	2	1	1	4	0	0	0	0	4	0	0	2.3
17870508	1	3	5	2	12	6	2	5	0	1	2	0	0	0	0	8	0	0	2.6
17720808	0	1	2	3	5	12	2	6	0	6	6	0	0	0	0	0	0	0	2.2
17720908	0	0	1	1	5	2	0	7	0	9	2	0	0	0	0	17	0	0	2.0
17750908	1	7	8	7	6	3	0	2	0	0	4	1	0	0	0	7	0	0	2.6
17910109	0	3	4	3	3	0	1	0	1	3	2	0	0	0	0	1	0	1	2.3
17870509	0	2	4	1	5	3	3	9	0	13	6	0	0	0	0	2	0	0	2.0
17720809	1	3	3	2	5	4	2	3	0	1	1	0	0	0	0	0	0	0	2.7
17720909	0	2	0	0	2	1	3	3	0	2	5	0	0	0	0	28	0	1	1.9
17750909	0	7	5	3	5	0	2	2	0	0	0	0	0	0	0	0	0	0	2.9
17910110	3	1	1	2	3	2	0	2	0	1	5	0	0	0	0	3	0	0	2.2
17720810	4	4	3	4	8	0	2	2	0	3	2	0	0	0	0	2	0	0	2.6
17720910	0	0	2	1	3	1	1	6	0	6	9	0	0	0	0	17	0	0	1.6
17851210	1	3	6	2	3	1	1	0	0	3	4	0	0	0	0	0	0	0	2.3
17910111	2	2	4	1	2	0	1	4	0	1	7	0	0	0	0	0	0	0	2.0
17760311	1	9	8	2	6	5	2	1	0	4	2	0	0	0	0	4	0	0	2.7
17720911	0	1	0	2	1	2	0	4	0	8	14	0	0	0	0	15	0	0	1.2
17910112	3	3	1	2	1	1	0	4	0	0	4	0	0	0	0	2	0	0	2.4

Appendix B: Sample Data for Faculty/Course Evaluation By Students

courseid	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	eval_avc
17830101	4.6	4.4	4.7	4.7	4.5	3.9	4.3	4.7	4.9	4.9	4.7	4.9	3.8	3.7	3.5	3.2	4.1	4.3
17910101	4.2	4.2	4.2	4.4	4.2	4.3	4.2	4.5	4.2	4.3	4.3	4.2	4.4	4.1	4.0	3.9	4.2	4.2
17910201	4.4	4.3	4.8	4.8	4.4	4.3	4.4	4.6	4.8	4.8	4.9	4.9	4.3	4.0	3.9	4.6	4.1	4.5
17720801	3.1	3.5	3.7	3.1	3.0	2.5	3.0	3.1	3.8	3.6	3.4	4.1	2.9	2.7	2.9	3.3	2.9	3.2
17720901	3.7	3.8	3.9	4.0	3.5	3.1	3.3	3.5	3.7	3.9	4.2	4.2	2.9	3.2	2.6	3.5	3.1	3.5
17830102	4.2	4.3	4.3	4.4	3.9	3.1	3.6	3.7	4.5	4.5	4.6	4.6	3.6	3.3	3.5	3.9	3.6	4.0
17910102	4.8	4.5	4.6	4.7	4.8	3.4	4.2	4.8	4.4	4.7	4.8	4.8	4.0	4.3	4.0	4.4	4.2	4.4
17720802	4.6	4.4	4.6	4.7	4.7	4.2	4.4	4.8	4.6	4.6	4.7	4.8	4.3	4.4	4.1	4.4	4.4	4.5
17720902	4.5	4.3	4.4	4.5	4.5	4.0	4.3	4.3	4.4	4.6	4.6	4.5	3.8	4.0	3.9	4.2	3.9	4.3
17910103	4.1	4.1	4.2	4.1	3.9	3.8	3.7	3.8	4.1	3.7	3.7	3.8	3.3	3.5	3.3	3.7	3.5	3.8
17720803	4.5	4.5	4.6	4.6	4.4	4.2	4.3	4.5	4.5	4.6	4.5	4.6	4.2	4.1	4.1	4.4	4.2	4.4
17820803	4.0	4.3	4.5	4.1	4.3	3.5	3.8	4.1	4.5	4.3	4.3	4.6	3.8	3.6	3.4	3.8	3.9	4.0
17720903	4.3	4.3	4.2	4.4	4.2	3.8	3.9	4.0	4.2	4.2	4.4	4.4	3.5	3.7	3.6	3.5	3.7	4.0
17921203	4.2	4.2	4.2	4.3	4.3	3.7	3.9	4.2	4.3	4.4	4.3	4.4	3.3	3.6	3.5	4.0	3.7	4.0
17720904	2.2	2.5	2.8	3.3	2.7	2.1	2.3	2.7	2.6	3.2	3.2	3.1	2.2	2.0	2.2	2.4	2.5	2.6
17750904	4.3	4.4	4.5	4.5	4.5	3.8	4.3	4.4	4.6	4.7	4.7	4.7	4.1	4.1	4.0	4.3	4.2	4.4
17851204	4.3	4.4	4.5	4.5	4.4	3.7	4.0	4.3	4.4	4.4	4.5	4.4	3.9	3.8	3.7	4.1	3.9	4.2
17910105	3.6	3.9	3.5	4.0	3.9	3.1	3.1	3.6	4.1	3.9	4.3	4.3	3.0	3.3	3.6	3.9	3.3	3.7
17720805	3.8	3.9	4.0	4.1	3.8	2.9	3.8	3.9	4.5	4.2	4.4	4.6	2.8	2.9	2.6	3.4	3.0	3.7
17750905	4.2	4.0	4.3	4.2	4.2	3.2	3.6	4.0	4.4	4.3	4.5	4.5	3.6	3.6	3.6	4.0	3.6	4.0
17851205	3.4	3.1	4.0	3.6	3.5	2.8	3.5	4.5	4.7	4.0	4.3	4.6	2.4	3.0	2.5	3.1	3.1	3.5
17770306	3.9	3.9	4.1	4.2	4.1	3.3	3.6	3.9	4.3	4.1	4.3	4.3	3.5	3.6	3.4	4.1	3.7	3.9
17870506	4.4	4.5	4.8	4.8	4.9	3.6	4.0	4.9	4.4	4.5	4.9	4.9	3.6	3.5	3.7	3.8	4.1	4.3
17720806	3.0	3.1	3.7	3.7	3.0	2.4	2.9	3.4	4.1	3.6	3.9	4.2	2.4	2.4	2.4	3.1	2.5	3.2
17750906	4.3	4.2	4.2	4.3	4.3	3.9	4.0	4.4	4.5	4.5	4.6	4.6	3.9	4.1	3.8	4.0	3.9	4.2
17851206	3.8	3.9	4.2	4.1	3.7	3.1	3.6	4.0	4.3	4.3	4.3	4.6	3.5	3.7	3.1	3.8	3.4	3.8
17910107	4.8	4.8	4.9	4.9	4.8	4.4	4.6	4.9	4.9	4.9	4.8	4.8	4.5	4.3	4.3	4.5	4.3	4.7
17760307	2.9	2.9	3.3	3.3	3.1	2.2	2.3	2.9	3.1	3.7	3.7	3.7	2.5	2.2	2.3	2.4	2.8	2.9
17870507	3.8	3.9	3.9	4.1	3.9	3.1	3.0	3.9	4.2	4.1	4.2	4.4	3.1	3.0	2.9	3.2	3.1	3.6
17910607	4.1	4.3	4.3	4.4	4.2	4.1	4.0	4.6	4.1	4.3	4.6	4.8	3.9	3.9	3.6	3.8	4.1	4.2
17720807	3.8	4.0	4.5	4.6	4.1	3.0	3.1	4.1	4.5	4.2	4.6	4.8	2.7	2.4	2.5	3.5	3.0	3.7
17720907	4.3	4.4	4.3	4.5	4.4	4.0	4.0	4.5	4.4	4.5	4.3	4.5	4.2	4.0	4.0	4.3	4.0	4.3
17851207	4.4	4.4	4.6	4.4	4.3	4.4	4.4	4.0	4.4	4.5	3.8	4.3	4.0	4.0	3.8	3.6	4.0	4.2
17910108	2.8	3.4	3.3	3.7	2.8	2.2	2.3	3.1	3.6	3.3	3.7	3.9	2.3	2.2	2.2	2.4	2.5	2.9
17870508	3.6	4.1	4.1	4.1	4.0	3.2	3.5	3.9	4.3	3.9	4.5	4.5	3.4	3.1	3.1	3.9	3.3	3.8
17720808	4.1	4.0	4.2	4.2	4.3	3.5	4.0	4.4	4.4	4.3	4.3	4.4	3.5	3.8	3.5	3.5	3.7	4.0
17720908	3.3	3.7	3.9	3.8	2.9	2.3	2.9	3.3	3.7	3.7	3.5	3.0	2.6	2.5	2.5	3.0	2.8	3.1
17750908	3.2	3.5	3.9	3.9	3.6	2.8	3.1	3.7	3.9	3.7	4.2	4.2	3.1	3.0	2.8	3.2	2.9	3.4
17910109	4.6	4.5	4.7	4.8	4.8	4.4	4.6	4.6	4.8	4.8	4.8	4.8	4.3	4.6	4.3	4.1	4.3	4.6
17870509	3.9	3.9	4.2	4.2	4.3	3.5	3.5	4.1	4.3	4.2	4.1	4.6	3.3	3.1	3.0	3.5	3.2	3.8
17720809	4.5	4.3	4.5	4.6	4.6	3.8	4.1	4.6	4.5	4.4	4.6	4.7	4.1	3.6	3.8	4.2	3.7	4.3
17720909	3.8	3.8	4.1	4.1	3.5	3.5	3.9	3.8	4.2	4.1	4.4	4.2	3.3	3.0	3.1	3.5	3.6	3.8
17750909	3.2	3.5	3.8	3.9	3.3	2.5	2.9	3.7	3.7	3.7	3.9	4.1	3.0	2.9	2.7	3.1	2.9	3.3
17910110	4.6	4.5	4.6	4.8	4.3	4.6	3.9	4.3	4.3	4.5	3.4	4.2	4.2	3.8	3.8	4.4	3.8	4.2
17720810	4.6	4.6	4.8	4.9	4.8	4.0	4.4	5.0	4.9	5.0	4.9	4.9	4.6	4.2	4.3	4.3	4.4	4.6
17720910	4.4	4.3	4.3	4.5	4.5	4.2	4.1	4.3	4.3	4.2	4.3	4.5	4.1	3.8	3.9	4.3	3.8	4.2
17851210	4.4	4.5	4.6	4.6	4.5	4.2	4.4	4.4	4.5	4.7	4.7	4.7	4.3	4.4	4.3	4.6	4.3	4.5
17910111	4.3	4.4	4.5	4.7	4.4	3.8	4.1	4.6	4.4	4.7	4.6	4.6	4.0	3.7	4.0	4.3	4.1	4.3
17760311	3.8	3.8	4.0	4.0	4.2	3.0	3.6	4.2	4.0	4.2	4.3	4.3	3.5	3.4	3.2	3.7	3.4	3.8
17720911	4.1	4.1	4.0	4.5	4.3	3.5	3.9	4.5	4.3	4.0	4.5	4.5	3.6	3.5	3.4	3.6	3.7	4.0
17910112	4.7	4.7	4.7	4.7	4.8	4.3	4.4	4.7	4.4	4.7	4.8	4.8	4.0	4.1	3.9	4.7	4.2	4.5

Appendix C: Grading System Using +/ - System

Letter Grade	Quality Points
A+	4.30
A	4.00
A-	3.70
B+	3.30
B	3.00
B-	2.70
C+	2.30
C	2.00
C-	1.70
D	1.00
F	0.00
WF	0.00
IP	0.00

Appendix D: SAS Output of Proc Factor for Principal Components

The FACTOR Procedure
Initial Factor Method: Principal Components

Prior Communality Estimates: ONE

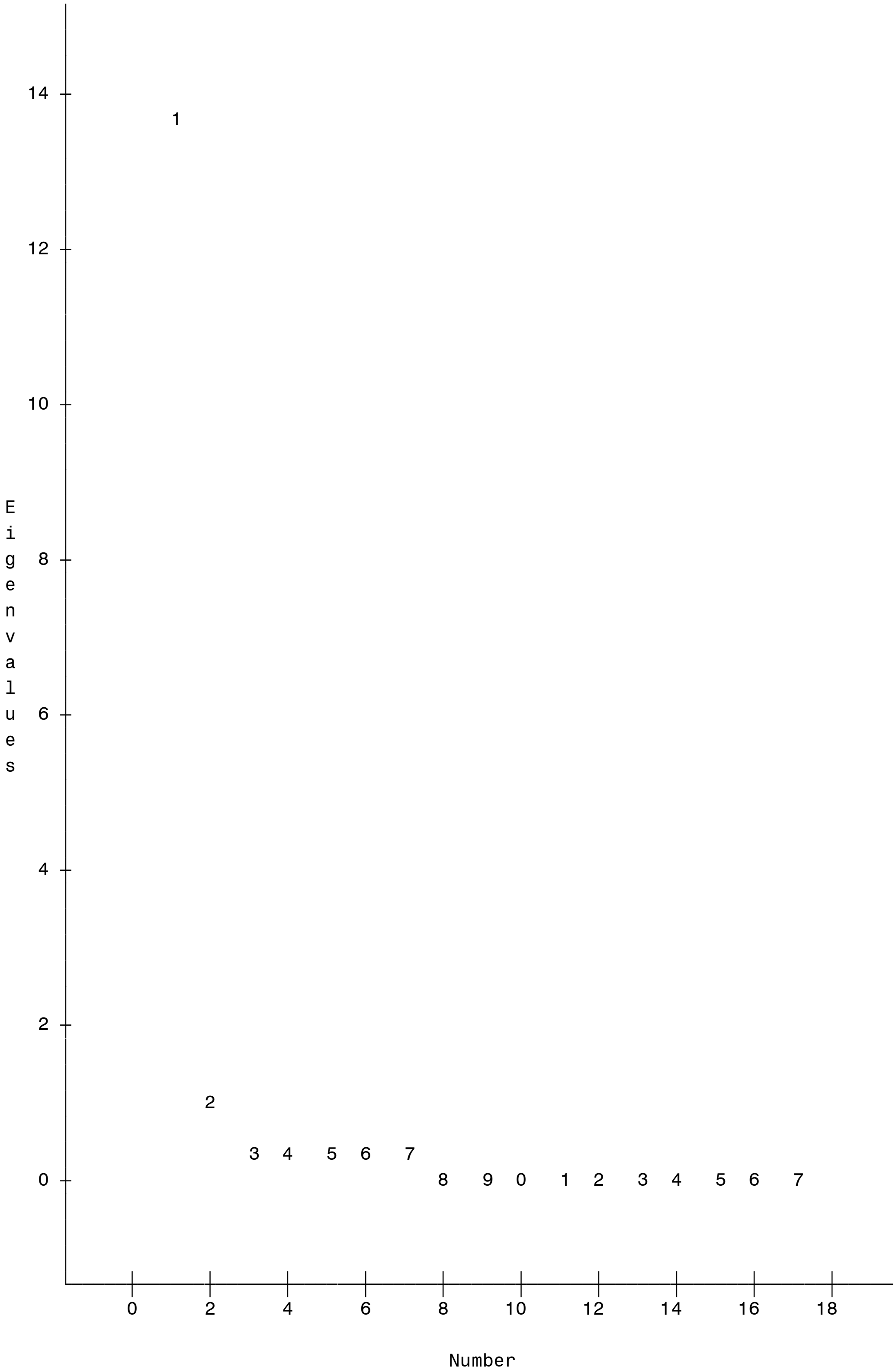
Eigenvalues of the Correlation Matrix: Total = 17 Average = 1

	Eigenvalue	Difference	Proportion	Cumulative
1	13.8189018	12.7519097	0.8129	0.8129
2	1.0669921	0.6193382	0.0628	0.8756
3	0.4476539	0.1136826	0.0263	0.9020
4	0.3339714	0.0897036	0.0196	0.9216
5	0.2442678	0.0285057	0.0144	0.9360
6	0.2157621	0.0394888	0.0127	0.9487
7	0.1762733	0.0296302	0.0104	0.9590
8	0.1466431	0.0402002	0.0086	0.9677
9	0.1064429	0.0118077	0.0063	0.9739
10	0.0946352	0.0062324	0.0056	0.9795
11	0.0884028	0.0166700	0.0052	0.9847
12	0.0717328	0.0084408	0.0042	0.9889
13	0.0632920	0.0214280	0.0037	0.9926
14	0.0418640	0.0055531	0.0025	0.9951
15	0.0363109	0.0104523	0.0021	0.9972
16	0.0258587	0.0048633	0.0015	0.9988
17	0.0209953		0.0012	1.0000

2 factors will be retained by the NFACTOR criterion.

Initial Factor Method: Principal Components

Scree Plot of Eigenvalues



The FACTOR Procedure
Initial Factor Method: Principal Components

Factor Pattern

		Factor1	Factor2
Q1	Faculty Member Explained the goals of this course clearly	93 *	0
Q2	Faculty Member Explained the grading system clearly	92 *	7
Q3	Faculty Member Gave assignments related to the goals of this course	90 *	22
Q4	Faculty Member Followed the plan for the course as established in the syllabus	89 *	27
Q5	Faculty Member Was well prepared	95 *	10
Q6	Faculty Member Spoke in a way that communicated the subject in an understandable manner	90 *	-30
Q7	Faculty Member Responded constructively and thoughtfully to questions and comments	95 *	-17
Q8	Faculty Member Used class time effectively	91 *	17
Q9	Faculty Member Had designated office and student appointment hours and was available to students during these times	85 *	26
Q10	Faculty Member Assigned grades fairly	91 *	24
Q11	Faculty Member Returned test results and evaluations of my work in a reasonable period of time	83 *	42 *
Q12	Faculty Member Met the class according to the published Schedule of Classes	82 *	25
Q13	Faculty Member Stimulated my thinking and gave me new insights into the subject	89 *	-37 *
Q14	Faculty Member Related well to students	92 *	-31
Q15	Faculty Member Motivated me to learn	92 *	-33
Q16	Faculty Member Assigned readings (including the text(s)) that contributed to what I learned	88 *	-18
Q17	Considering both the limitations and possibilities of the subject matter and course, how would you rate the overall teaching effectiveness of the instructor?	95 *	-23

Printed values are multiplied by 100 and rounded to the nearest integer. Values greater than 0.35 are flagged by an '*'.

Variance Explained by Each Factor

Factor1	Factor2
13.818902	1.066992

Final Communality Estimates: Total = 14.885894

Q1	Q2	Q3	Q4	Q5	Q6
0.86003084	0.84673699	0.85810404	0.86788248	0.90302620	0.90838167

Q7	Q8	Q9	Q10	Q11	Q12
0.92425149	0.86476575	0.79175664	0.88305195	0.85386497	0.73952811

Q13	Q14	Q15	Q16	Q17
0.93200663	0.93671321	0.95123470	0.80778656	0.95677169

The FACTOR Procedure
Rotation Method: Varimax

Orthogonal Transformation Matrix

	1	2
1	0.70765	0.70656
2	0.70656	-0.70765

Rotated Factor Pattern

		Factor1	Factor2
Q1	Faculty Member Explained the goals of this course clearly	65 *	66 *
Q2	Faculty Member Explained the grading system clearly	70 *	60 *
Q3	Faculty Member Gave assignments related to the goals of this course	79 *	48 *
Q4	Faculty Member Followed the plan for the course as established in the syllabus	82 *	44 *
Q5	Faculty Member Was well prepared	74 *	60 *
Q6	Faculty Member Spoke in a way that communicated the subject in an understandable manner	43 *	85 *
Q7	Faculty Member Responded constructively and thoughtfully to questions and comments	55 *	79 *
Q8	Faculty Member Used class time effectively	77 *	52 *
Q9	Faculty Member Had designated office and student appointment hours and was available to students during these times	78 *	42 *
Q10	Faculty Member Assigned grades fairly	81 *	48 *
Q11	Faculty Member Returned test results and evaluations of my work in a reasonable period of time	88 *	29
Q12	Faculty Member Met the class according to the published Schedule of Classes	76 *	40 *
Q13	Faculty Member Stimulated my thinking and gave me new insights into the subject	37 *	89 *
Q14	Faculty Member Related well to students	43 *	87 *
Q15	Faculty Member Motivated me to learn	42 *	88 *
Q16	Faculty Member Assigned readings (including the text(s)) that contributed to what I learned	50 *	75 *
Q17	Considering both the limitations and possibilities of the subject matter and course, how would you rate the overall teaching effectiveness of the instructor?	51 *	83 *

Printed values are multiplied by 100 and rounded to the nearest integer. Values greater than 0.35 are flagged by an '*'.

Appendix E : Output for the Pearson's Correlation Coefficients

The CORR Procedure

Pearson Correlation Coefficients, N = 102
Prob > |r| under H0: Rho=0

	Q1	Q2	Q3	Q4
grade_avg	0.05480	0.08845	0.17478	0.04737
Course Grade Average Per Student	0.5844	0.3767	0.0789	0.6364

Pearson Correlation Coefficients, N = 102
Prob > |r| under H0: Rho=0

	Q5	Q6	Q7	Q8
grade_avg	0.09074	0.02270	0.06990	0.07109
Course Grade Average Per Student	0.3644	0.8208	0.4851	0.4777

Pearson Correlation Coefficients, N = 102
Prob > |r| under H0: Rho=0

	Q9	Q10	Q11	Q12
grade_avg	0.07028	0.22069	0.20730	0.12439
Course Grade Average Per Student	0.4828	0.0258	0.0366	0.2129

Pearson Correlation Coefficients, N = 102
Prob > |r| under H0: Rho=0

	Q13	Q14	Q15	Q16
grade_avg	0.02850	0.07099	0.03926	0.08979
Course Grade Average Per Student	0.7761	0.4783	0.6952	0.3695

Pearson Correlation Coefficients, N = 102
Prob > |r| under H0: Rho=0

	Q17
grade_avg	0.04188
Course Grade Average Per Student	0.6760

Appendix F : Output for the Spearman's Rank Correlation Coefficients

Spearman Correlation Coefficients, N = 102
Prob > |r| under H0: Rho=0

	Q1	Q2	Q3	Q4
grade_avg	0.04820	0.10550	0.20523	0.09281
Course Grade Average Per Student	0.6305	0.2913	0.0385	0.3535

Spearman Correlation Coefficients, N = 102
Prob > |r| under H0: Rho=0

	Q5	Q6	Q7	Q8
grade_avg	0.10728	0.02033	0.09510	0.11249
Course Grade Average Per Student	0.2832	0.8393	0.3417	0.2603

Spearman Correlation Coefficients, N = 102
Prob > |r| under H0: Rho=0

	Q9	Q10	Q11	Q12
grade_avg	0.02010	0.25703	0.26933	0.14361
Course Grade Average Per Student	0.8411	0.0091	0.0062	0.1499

Spearman Correlation Coefficients, N = 102
Prob > |r| under H0: Rho=0

	Q13	Q14	Q15	Q16
grade_avg	0.01806	0.07000	0.03926	0.07977
Course Grade Average Per Student	0.8570	0.4845	0.6952	0.4255

Spearman Correlation Coefficients, N = 102
Prob > |r| under H0: Rho=0

	Q17
grade_avg	0.06051
Course Grade Average Per Student	0.5457

Appendix G : Output for the Kendall's Rank Correlation Coefficients

Kendall Tau b Correlation Coefficients, N = 102
Prob > |tau| under H0: Tau=0

	Q1	Q2	Q3	Q4
grade_avg	0.03550	0.07293	0.13869	0.05975
Course Grade Average Per Student	0.5986	0.2782	0.0392	0.3747

Kendall Tau b Correlation Coefficients, N = 102
Prob > |tau| under H0: Tau=0

	Q5	Q6	Q7	Q8
grade_avg	0.07212	0.01556	0.05780	0.06771
Course Grade Average Per Student	0.2834	0.8171	0.3904	0.3143

Kendall Tau b Correlation Coefficients, N = 102
Prob > |tau| under H0: Tau=0

	Q9	Q10	Q11	Q12
grade_avg	0.01556	0.16719	0.17384	0.09332
Course Grade Average Per Student	0.8171	0.0130	0.0098	0.1660

Kendall Tau b Correlation Coefficients, N = 102
Prob > |tau| under H0: Tau=0

	Q13	Q14	Q15	Q16
grade_avg	0.01636	0.04653	0.01946	0.05797
Course Grade Average Per Student	0.8081	0.4895	0.7724	0.3888

Kendall Tau b Correlation Coefficients, N = 102
Prob > |tau| under H0: Tau=0

	Q17
grade_avg	0.04984
Course Grade Average Per Student	0.4591

Appendix H : Proof for Sum of the Squares for the First N Numbers

a) Sum of the Squares for the First n Natural Numbers

$$\sum_{k=0}^{n} k^2 = \frac{n}{6}(n+1)(2n+1)$$

Proof

$$\sum_{k=0}^{n} k^3 = \sum_{k=0}^{n} (k+1)^3 - (n+1)^3$$

Expending the sums we have:

$$\sum_{k=0}^{n} k^3 = \sum_{k=0}^{n} k^3 + 3\sum_{k=0}^{n} k^2 + 3\sum_{k=0}^{n} k + \sum_{k=0}^{n} 1 - (n+1)^3$$

Rearrange the formula to have the sum of squares on the left:

$$3\sum_{k=0}^{n} k^2 = (n+1)^3 - 3\sum_{k=0}^{n} k - \sum_{k=0}^{n} 1$$

$$3\sum_{k=0}^{n} k^2 = n^3 + 3n^2 + 3n + 1 - \frac{3}{2}(n(n+1)) - (n+1)$$

$$3\sum_{k=0}^{n} k^2 = n^3 + \frac{3}{2}n^2 + \frac{n}{2}$$

Hence, $$\sum_{k=0}^{n} k^2 = \frac{n}{6}(n+1)(2n+1)$$

b) The sum of the squares of the first n odd natural numbers

$$\sum_{k=1}^{k=n}(2k-1)^2 = 1^2 + 3^2 + 5^2 + ... + (2n-1)^2 = \frac{n(2n-1)(2n+1)}{3}$$

Proof By Induction

1) For n = 1 it's true.
2) For n =2 we have 1 + 9 = 10. This is equal to 2*3*5/3=10.

3) Let's consider that is true for n, and let's prove it for n+1.

$$\frac{n(2n-1)(2n+1)}{3} + (2n+1)^2 = \frac{(2n+1)(2n^2-n+6n+3)}{3}$$
$$= \frac{(2n-1)(2n^2+5n+3)}{3} = \frac{(n+1)(2n+1)(2n+3)}{3}$$

Hence, for any natural number n, the sum of the squares of the first n odd natural numbers is:

$$\frac{n(2n-1)(2n+1)}{3}$$

Appendix I : Output of Proc Reg for Model with Principle Components

```
The REG Procedure
Model: MODEL1
Dependent Variable: grade_avg Course Grade Average Per Student

Number of Observations Read         102
Number of Observations Used         102


No variable met the 0.0500 significance level for entry into the model.
```

Appendix J : Output of Proc Reg for First Model with SEF Variables

Dependent Variable: grade_avg Course Grade Average Per Student

Number of Observations Read	102
Number of Observations Used	102

NOTE: No intercept in model. R-Square is redefined.

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	683.33323	170.83331	755.58	<.0001
Error	98	22.15737	0.22610		
Uncorrected Total	102	705.49060			

Root MSE	0.47550	R-Square	0.9686
Dependent Mean	2.58172	Adj R-Sq	0.9673
Coeff Var	18.41779		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value
Q1	Faculty Member Explained the goals of this course clearly	1	-0.31926	0.15754	-2.03
Q8	Faculty Member Used class time effectively	1	-0.47466	0.18862	-2.52
Q10	Faculty Member Assigned grades fairly	1	0.94109	0.25527	3.69
Q11	Faculty Member Returned test results and evaluations of my work in a reasonable period of time	1	0.41021	0.19547	2.10

Parameter Estimates

Variable	Label	DF	Pr > |t|	Variance Inflation
Q1	Faculty Member Explained the goals of this course clearly	1	0.0454	192.21568
Q8	Faculty Member Used class time effectively	1	0.0135	281.61273
Q10	Faculty Member Assigned grades fairly	1	0.0004	550.63313
Q11	Faculty Member Returned test results and evaluations of my work in a reasonable period of time	1	0.0384	336.59749

'

The REG Procedure
Model: MODEL1
Dependent Variable: grade_avg Course Grade Average Per Student

Correlation of Estimates

Variable	Label	Q1	Q8	Q10	Q11
Q1	Faculty Member Explained the goals of this course clearly	1.0000	-0.3766	-0.3771	0.0728
Q8	Faculty Member Used class time effectively	-0.3766	1.0000	-0.3392	-0.1954
Q10	Faculty Member Assigned grades fairly	-0.3771	-0.3392	1.0000	-0.6840
Q11	Faculty Member Returned test results and evaluations of my work in a reasonable period of time	0.0728	-0.1954	-0.6840	1.0000

Collinearity Diagnostics

Number	Eigenvalue	Condition Index
1	3.99120	1.00000
2	0.00480	28.82609
3	0.00273	38.26979
4	0.00127	55.99765

Collinearity Diagnostics

	Proportion of Variation			
Number	Q1	Q8	Q10	Q11
1	0.00032553	0.00022246	0.00011387	0.00018606
2	0.64789	0.00114	0.01802	0.21811
3	0.23653	0.95469	0.01742	0.12787
4	0.11525	0.04395	0.96444	0.65383

'

The REG Procedure
Model: MODEL1
Dependent Variable: grade_avg Course Grade Average Per Student

Collinearity Diagnostics
(intercept adjusted)

Number	Eigenvalue	Condition Index
1	3.99120	1.00000
2	0.00480	28.82609
3	0.00273	38.26979
4	0.00127	55.99765

Collinearity Diagnostics (intercept adjusted)

	-----------------Proportion of Variation----------------			
Number	Q1	Q8	Q10	Q11
1	0.00032553	0.00022246	0.00011387	0.00018606
2	0.64789	0.00114	0.01802	0.21811
3	0.23653	0.95469	0.01742	0.12787
4	0.11525	0.04395	0.96444	0.65383

Appendix K : Output of the Proc Reg with Interaction Terms in the Model

All interaction terms in the model

The REG Procedure
Model: MODEL1
Dependent Variable: grade_avg Course Grade Average Per Student

Number of Observations Read	102
Number of Observations Used	102

NOTE: No intercept in model. R-Square is redefined.

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	13	685.31232	52.71633	232.52	<.0001
Error	89	20.17828	0.22672		
Uncorrected Total	102	705.49060			

Root MSE	0.47615	R-Square	0.9714
Dependent Mean	2.58172	Adj R-Sq	0.9672
Coeff Var	18.44329		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Q1	Faculty Member Explained the goals of this course clearly	1	4.24495	8.81782	0.48	0.6314	600486
Q8	Faculty Member Used class time effectively	1	-0.13654	3.15730	-0.04	0.9656	78688
Q10	Faculty Member Assigned grades fairly	1	-15.59637	17.36593	-0.90	0.3716	2541225
Q11	Faculty Member Returned test results and evaluations of my work in a reasonable period of time	1	14.43488	13.26509	1.09	0.2795	1545789
intq1q8		1	-1.18199	2.60968	-0.45	0.6517	969195
intq1q10		1	3.67866	3.51917	1.05	0.2987	1861932
intQ1Q11		1	-4.40583	4.24134	-1.04	0.3017	2797674
intq8q10		1	3.94693	4.44992	0.89	0.3775	3043583
intq8q11		1	-3.39412	3.62638	-0.94	0.3518	2096190
intq10q11		1	0.25359	2.31936	0.11	0.9132	909187
intQ1Q8Q10		1	-0.86674	0.87826	-0.99	0.3264	2199261
intQ1Q8Q11		1	1.05550	1.08518	0.97	0.3334	3459091
intQ8Q10Q11		1	-0.06248	0.56965	-0.11	0.9129	1027183

The model with interaction term intQ10Q11 removed

The REG Procedure
Model: MODEL1
Dependent Variable: grade_avg Course Grade Average Per Student

Number of Observations Read	102
Number of Observations Used	102

NOTE: No intercept in model. R-Square is redefined.

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	12	685.30961	57.10913	254.69	<.0001
Error	90	20.18099	0.22423		
Uncorrected Total	102	705.49060			

Root MSE	0.47353	R-Square	0.9714
Dependent Mean	2.58172	Adj R-Sq	0.9676
Coeff Var	18.34177		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Q1	Faculty Member Explained the goals of this course clearly	1	3.33131	2.80011	1.19	0.2373	61225
Q8	Faculty Member Used class time effectively	1	-0.31225	2.70275	-0.12	0.9083	58302
Q10	Faculty Member Assigned grades fairly	1	-14.48275	13.98799	-1.04	0.3033	1667063
Q11	Faculty Member Returned test results and evaluations of my work in a reasonable period of time	1	14.30214	13.13671	1.09	0.2792	1532839
intq1q8		1	-0.94065	1.38457	-0.68	0.4986	275842
intq1q10		1	3.64628	3.48738	1.05	0.2986	1848743
intQ1Q11		1	-4.13335	3.41303	-1.21	0.2290	1831740
intq8q10		1	3.69606	3.79179	0.97	0.3323	2234412
intq8q11		1	-3.32094	3.54446	-0.94	0.3513	2024785
intQ1Q8Q10		1	-0.85881	0.87044	-0.99	0.3265	2184243
intQ1Q8Q11		1	0.98515	0.86906	1.13	0.2600	2243117
intQ8Q10Q11		1	-0.00586	0.23609	-0.02	0.9803	178400

The model with interaction term intQ8Q10Q11 removed

The REG Procedure
Model: MODEL1
Dependent Variable: grade_avg Course Grade Average Per Student

Number of Observations Read	102
Number of Observations Used	102

NOTE: No intercept in model. R-Square is redefined.

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	685.30947	62.30086	280.92	<.0001
Error	91	20.18112	0.22177		
Uncorrected Total	102	705.49060			

Root MSE	0.47093	R-Square	0.9714
Dependent Mean	2.58172	Adj R-Sq	0.9679
Coeff Var	18.24078		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Q1	Faculty Member Explained the goals of this course clearly	1	3.27685	1.72999	1.89	0.0614	23630
Q8	Faculty Member Used class time effectively	1	-0.27555	2.24995	-0.12	0.9028	40852
Q10	Faculty Member Assigned grades fairly	1	-14.45171	13.85527	-1.04	0.2997	1653741
Q11	Faculty Member Returned test results and evaluations of my work in a reasonable period of time	1	14.30167	13.06436	1.09	0.2765	1532836
intq1q8		1	-0.90947	0.57910	-1.57	0.1198	48789
intq1q10		1	3.64510	3.46786	1.05	0.2960	1848398
intQ1Q11		1	-4.12725	3.38544	-1.22	0.2260	1822263
intq8q10		1	3.66830	3.60312	1.02	0.3113	2039997
intq8q11		1	-3.33450	3.48286	-0.96	0.3409	1976725
intQ1Q8Q10		1	-0.85991	0.86452	-0.99	0.3225	2178549
intQ1Q8Q11		1	0.98092	0.84749	1.16	0.2501	2156860

The model with interaction term intq8q11 removed

The REG Procedure
Model: MODEL1
Dependent Variable: grade_avg Course Grade Average Per Student

Number of Observations Read	102
Number of Observations Used	102

NOTE: No intercept in model. R-Square is redefined.

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	685.10619	68.51062	309.21	<.0001
Error	92	20.38440	0.22157		
Uncorrected Total	102	705.49060			

Root MSE	0.47071	R-Square	0.9711
Dependent Mean	2.58172	Adj R-Sq	0.9680
Coeff Var	18.23251		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Q1	Faculty Member Explained the goals of this course clearly	1	3.25818	1.72910	1.88	0.0627	23627
Q8	Faculty Member Used class time effectively	1	-0.67673	2.20958	-0.31	0.7601	39435
Q10	Faculty Member Assigned grades fairly	1	-1.54093	3.17928	-0.48	0.6291	87154
Q11	Faculty Member Returned test results and evaluations of my work in a reasonable period of time	1	2.13222	3.01688	0.71	0.4815	81815
intq1q8		1	-0.81321	0.57004	-1.43	0.1571	47319
intq1q10		1	0.60323	1.38910	0.43	0.6651	296849
intQ1Q11		1	-1.24750	1.55295	-0.80	0.4239	383788
intq8q10		1	0.23350	0.33356	0.70	0.4857	17499
intQ1Q8Q10		1	-0.05671	0.20866	-0.27	0.7864	127025
intQ1Q8Q11		1	0.19868	0.22502	0.88	0.3796	152185

The model with interaction term intQ1Q8Q10 removed

The REG Procedure
Model: MODEL1
Dependent Variable: grade_avg Course Grade Average Per Student

Number of Observations Read	102
Number of Observations Used	102

NOTE: No intercept in model. R-Square is redefined.

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	685.08983	76.12109	347.01	<.0001
Error	93	20.40077	0.21936		
Uncorrected Total	102	705.49060			

Root MSE	0.46836	R-Square	0.9711
Dependent Mean	2.58172	Adj R-Sq	0.9683
Coeff Var	18.14150		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Q1	Faculty Member Explained the goals of this course clearly	1	3.01960	1.48230	2.04	0.0445	17538
Q8	Faculty Member Used class time effectively	1	-0.41824	1.98448	-0.21	0.8335	32130
Q10	Faculty Member Assigned grades fairly	1	-0.92675	2.22523	-0.42	0.6780	43125
Q11	Faculty Member Returned test results and evaluations of my work in a reasonable period of time	1	1.46420	1.74078	0.84	0.4024	27514
intq1q8		1	-0.81086	0.56713	-1.43	0.1561	47308
intq1q10		1	0.26201	0.59154	0.44	0.6588	54372
intQ1Q11		1	-0.84654	0.48275	-1.75	0.0828	37459
intq8q10		1	0.18952	0.29024	0.65	0.5154	13382
intQ1Q8Q11		1	0.13971	0.05931	2.36	0.0206	10678

The model with interaction term intq1q10 removed

The REG Procedure
Model: MODEL1
Dependent Variable: grade_avg Course Grade Average Per Student

Number of Observations Read	102
Number of Observations Used	102

NOTE: No intercept in model. R-Square is redefined.

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	685.04679	85.63085	393.73	<.0001
Error	94	20.44381	0.21749		
Uncorrected Total	102	705.49060			

Root MSE	0.46636	R-Square	0.9710
Dependent Mean	2.58172	Adj R-Sq	0.9686
Coeff Var	18.06377		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Q1	Faculty Member Explained the goals of this course clearly	1	3.05649	1.47362	2.07	0.0408	17483
Q8	Faculty Member Used class time effectively	1	-1.02756	1.42415	-0.72	0.4724	16690
Q10	Faculty Member Assigned grades fairly	1	-0.05733	1.04364	-0.05	0.9563	9567.66247
Q11	Faculty Member Returned test results and evaluations of my work in a reasonable period of time	1	0.99522	1.37583	0.72	0.4713	17335
intq1q8		1	-0.66876	0.46567	-1.44	0.1543	32170
intQ1Q11		1	-0.69645	0.34234	-2.03	0.0447	19001
intq8q10		1	0.24288	0.26293	0.92	0.3580	11077
intQ1Q8Q11		1	0.12968	0.05459	2.38	0.0195	9124.45748

The model with interaction term intq8q10 removed

The REG Procedure
Model: MODEL1
Dependent Variable: grade_avg Course Grade Average Per Student

Number of Observations Read	102
Number of Observations Used	102

NOTE: No intercept in model. R-Square is redefined.

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	684.86120	97.83731	450.55	<.0001
Error	95	20.62940	0.21715		
Uncorrected Total	102	705.49060			

Root MSE	0.46600	R-Square	0.9708
Dependent Mean	2.58172	Adj R-Sq	0.9686
Coeff Var	18.04982		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Q1	Faculty Member Explained the goals of this course clearly	1	2.04340	0.98351	2.08	0.0404	7799.55376
Q8	Faculty Member Used class time effectively	1	-0.39774	1.24937	-0.32	0.7509	12865
Q10	Faculty Member Assigned grades fairly	1	0.87371	0.27068	3.23	0.0017	644.58566
Q11	Faculty Member Returned test results and evaluations of my work in a reasonable period of time	1	0.36012	1.19081	0.30	0.7630	13006
intq1q8		1	-0.55943	0.45003	-1.24	0.2169	30092
intQ1Q11		1	-0.52070	0.28439	-1.83	0.0702	13132
intQ1Q8Q11		1	0.12484	0.05429	2.30	0.0237	9040.38830

The model with interaction term intq1q8 removed

The REG Procedure
Model: MODEL1
Dependent Variable: grade_avg Course Grade Average Per Student

Number of Observations Read	102
Number of Observations Used	102

NOTE: No intercept in model. R-Square is redefined.

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	684.52564	114.08761	522.42	<.0001
Error	96	20.96495	0.21838		
Uncorrected Total	102	705.49060			

Root MSE	0.46732	R-Square	0.9703
Dependent Mean	2.58172	Adj R-Sq	0.9684
Coeff Var	18.10101		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Q1	Faculty Member Explained the goals of this course clearly	1	1.12004	0.64646	1.73	0.0864	3350.72879
Q8	Faculty Member Used class time effectively	1	-1.72825	0.64628	-2.67	0.0088	3422.91582
Q10	Faculty Member Assigned grades fairly	1	0.81353	0.26707	3.05	0.0030	623.96771
Q11	Faculty Member Returned test results and evaluations of my work in a reasonable period of time	1	1.64170	0.59763	2.75	0.0072	3257.33868
intQ1Q11		1	-0.61216	0.27548	-2.22	0.0286	12253
intQ1Q8Q11		1	0.07223	0.03410	2.12	0.0367	3545.36894

The model with interaction term intQ1Q8Q11 removed

The REG Procedure
Model: MODEL1
Dependent Variable: grade_avg Course Grade Average Per Student

Number of Observations Read	102
Number of Observations Used	102

NOTE: No intercept in model. R-Square is redefined.

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	683.54575	136.70915	604.28	<.0001
Error	97	21.94484	0.22624		
Uncorrected Total	102	705.49060			

Root MSE	0.47564	R-Square	0.9689
Dependent Mean	2.58172	Adj R-Sq	0.9673
Coeff Var	18.42348		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Q1	Faculty Member Explained the goals of this course clearly	1	-0.17056	0.21994	-0.78	0.4399	374.38444
Q8	Faculty Member Used class time effectively	1	-0.42172	0.19642	-2.15	0.0343	305.21455
Q10	Faculty Member Assigned grades fairly	1	0.85262	0.27118	3.14	0.0022	620.98777
Q11	Faculty Member Returned test results and evaluations of my work in a reasonable period of time	1	0.44534	0.19887	2.24	0.0274	348.16400
intQ1Q11		1	-0.03291	0.03396	-0.97	0.3348	179.71254

The model with interaction term intQ1Q11 removed

The REG Procedure
Model: MODEL1
Dependent Variable: grade_avg Course Grade Average Per Student

Number of Observations Read	102
Number of Observations Used	102

NOTE: No intercept in model. R-Square is redefined.

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	683.33323	170.83331	755.58	<.0001
Error	98	22.15737	0.22610		
Uncorrected Total	102	705.49060			

Root MSE	0.47550	R-Square	0.9686
Dependent Mean	2.58172	Adj R-Sq	0.9673
Coeff Var	18.41779		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Q1	Faculty Member Explained the goals of this course clearly	1	-0.31926	0.15754	-2.03	0.0454	192.21568
Q8	Faculty Member Used class time effectively	1	-0.47466	0.18862	-2.52	0.0135	281.61273
Q10	Faculty Member Assigned grades fairly	1	0.94109	0.25527	3.69	0.0004	550.63313
Q11	Faculty Member Returned test results and evaluations of my work in a reasonable period of time	1	0.41021	0.19547	2.10	0.0384	336.59749

Appendix L: SAS Output for Linear Regression Model with Variable Transformations

Model with Transformations: Q3 CubQ9 CubQ10 CubQ11 LogQ4 LogQ7 in

The REG Procedure
Model: MODEL1
Dependent Variable: logy

Number of Observations Read	102
Number of Observations Used	102

Stepwise Selection: Step 1

Variable CubQ10 Entered: R-Square = 0.0646 and C(p) = 6.7263

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.30113	0.30113	6.91	0.0099
Error	100	4.35816	0.04358		
Corrected Total	101	4.65930			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	0.72574	0.07938	3.64322	83.60	<.0001
CubQ10	0.00245	0.00093270	0.30113	6.91	0.0099

Bounds on condition number: 1, 1

Stepwise Selection: Step 2

Variable LogQ8 Entered: R-Square = 0.1612 and C(p) = -2.0840

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	0.75100	0.37550	9.51	0.0002
Error	99	3.90830	0.03948		
Corrected Total	101	4.65930			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	1.60425	0.27099	1.38356	35.05	<.0001
CubQ10	0.00732	0.00169	0.73756	18.68	<.0001
LogQ8	-0.90391	0.26777	0.44986	11.40	0.0011

Model with Transformations: Q3 CubQ9 CubQ10 CubQ11 LogQ4 LogQ7 in

The REG Procedure
Model: MODEL1
Dependent Variable: logy

Stepwise Selection: Step 2

Bounds on condition number: 3.6419, 14.568

Stepwise Selection: Step 3

Variable CubQ9 Entered: R-Square = 0.1944 and C(p) = -3.8009

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	0.90568	0.30189	7.88	<.0001
Error	98	3.75362	0.03830		
Corrected Total	101	4.65930			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	1.47750	0.27427	1.11151	29.02	<.0001
CubQ9	-0.00314	0.00156	0.15468	4.04	0.0472
CubQ10	0.00908	0.00188	0.88965	23.23	<.0001
LogQ8	-0.73788	0.27639	0.27300	7.13	0.0089

Bounds on condition number: 4.6453, 36.075

Stepwise Selection: Step 4

Variable Q3 Entered: R-Square = 0.2311 and C(p) = -5.9146

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	1.07687	0.26922	7.29	<.0001
Error	97	3.58242	0.03693		
Corrected Total	101	4.65930			

Model with Transformations: Q3 CubQ9 CubQ10 CubQ11 LogQ4 LogQ7 in

The REG Procedure
Model: MODEL1
Dependent Variable: logy

Stepwise Selection: Step 4

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	1.12430	0.31535	0.46944	12.71	0.0006
Q3	0.20787	0.09655	0.17119	4.64	0.0338
CubQ9	-0.00488	0.00173	0.29293	7.93	0.0059
CubQ10	0.00803	0.00191	0.64897	17.57	<.0001
LogQ8	-0.95704	0.28986	0.40261	10.90	0.0013

Bounds on condition number: 5.637, 78.001

Stepwise Selection: Step 5

Variable LogQ4 Entered: R-Square = 0.2773 and C(p) = -9.0855

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	1.29205	0.25841	7.37	<.0001
Error	96	3.36724	0.03508		
Corrected Total	101	4.65930			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	1.59563	0.36147	0.68349	19.49	<.0001
Q3	0.32279	0.10491	0.33206	9.47	0.0027
CubQ9	-0.00536	0.00170	0.34836	9.93	0.0022
CubQ10	0.00863	0.00188	0.73813	21.04	<.0001
LogQ4	-1.06297	0.42916	0.21518	6.13	0.0150
LogQ8	-0.55237	0.32632	0.10050	2.87	0.0938

Bounds on condition number: 7.0077, 145.83

Stepwise Selection: Step 6

Variable CubQ11 Entered: R-Square = 0.3317 and C(p) = -13.1793

Model with Transformations: Q3 CubQ9 CubQ10 CubQ11 LogQ4 LogQ7 in

The REG Procedure
Model: MODEL1
Dependent Variable: logy

Stepwise Selection: Step 6

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	1.54565	0.25761	7.86	<.0001
Error	95	3.11365	0.03278		
Corrected Total	101	4.65930			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	1.79534	0.35671	0.83023	25.33	<.0001
Q3	0.35875	0.10223	0.40360	12.31	0.0007
CubQ9	-0.00646	0.00169	0.47863	14.60	0.0002
CubQ10	0.00687	0.00193	0.41774	12.75	0.0006
CubQ11	0.00463	0.00166	0.25359	7.74	0.0065
LogQ4	-1.29422	0.42310	0.30668	9.36	0.0029
LogQ8	-0.68529	0.31904	0.15122	4.61	0.0343

Bounds on condition number: 7.1215, 207.23

Stepwise Selection: Step 7

Variable LogQ7 Entered: R-Square = 0.3593 and C(p) = -14.2710

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	1.67431	0.23919	7.53	<.0001
Error	94	2.98499	0.03176		
Corrected Total	101	4.65930			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	1.75132	0.35180	0.78696	24.78	<.0001
Q3	0.43740	0.10795	0.52136	16.42	0.0001
CubQ9	-0.00659	0.00167	0.49655	15.64	0.0001
CubQ10	0.00750	0.00192	0.48412	15.25	0.0002
CubQ11	0.00437	0.00164	0.22458	7.07	0.0092
LogQ4	-1.45585	0.42413	0.37415	11.78	0.0009
LogQ7	-0.45304	0.22507	0.12866	4.05	0.0470
LogQ8	-0.31516	0.36391	0.02382	0.75	0.3887

Model with Transformations: Q3 CubQ9 CubQ10 CubQ11 LogQ4 LogQ7 in

The REG Procedure
Model: MODEL1
Dependent Variable: logy

Stepwise Selection: Step 7

Bounds on condition number: 8.3626, 305.15

Stepwise Selection: Step 8

Variable LogQ8 Removed: R-Square = 0.3542 and C(p) = -15.6987

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	1.65049	0.27508	8.69	<.0001
Error	95	3.00880	0.03167		
Corrected Total	101	4.65930			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	1.69131	0.34445	0.76358	24.11	<.0001
Q3	0.44930	0.10693	0.55916	17.66	<.0001
CubQ9	-0.00672	0.00166	0.52198	16.48	0.0001
CubQ10	0.00730	0.00190	0.46520	14.69	0.0002
CubQ11	0.00413	0.00162	0.20647	6.52	0.0123
LogQ4	-1.63290	0.37112	0.61312	19.36	<.0001
LogQ7	-0.55153	0.19397	0.25606	8.08	0.0055

Bounds on condition number: 8.0626, 190.89

All variables left in the model are significant at the 0.1500 level.

No other variable met the 0.0500 significance level for entry into the model.

Summary of Stepwise Selection

Step	Variable Entered	Variable Removed	Label	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	CubQ10			1	0.0646	0.0646	6.7263	6.91	0.0099
2	LogQ8			2	0.0966	0.1612	-2.0840	11.40	0.0011
3	CubQ9			3	0.0332	0.1944	-3.8009	4.04	0.0472
4	Q3		Faculty Member Gave assignments related to the goals of this course	4	0.0367	0.2311	-5.9146	4.64	0.0338
5	LogQ4			5	0.0462	0.2773	-9.0855	6.13	0.0150
6	CubQ11			6	0.0544	0.3317	-13.179	7.74	0.0065

Model with Transformations: Q3 CubQ9 CubQ10 CubQ11 LogQ4 LogQ7 in

The REG Procedure
Model: MODEL1
Dependent Variable: logy

Summary of Stepwise Selection

Step	Variable Entered	Variable Removed	Label	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
7	LogQ7			7	0.0276	0.3593	-14.271	4.05	0.0470
8		LogQ8		6	0.0051	0.3542	-15.699	0.75	0.3887

Model with Transformations: Q3 CubQ9 CubQ10 CubQ11 LogQ4 LogQ7 in

The REG Procedure
Model: MODEL1
Dependent Variable: logy

Number of Observations Read	102
Number of Observations Used	102

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	1.65049	0.27508	8.69	<.0001
Error	95	3.00880	0.03167		
Corrected Total	101	4.65930			

Root MSE	0.17797	R-Square	0.3542
Dependent Mean	0.92720	Adj R-Sq	0.3135
Coeff Var	19.19393		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Intercept	Intercept	1	1.69131	0.34445	4.91	<.0001	0
Q3	Faculty Member Gave assignments related to the goals of this course	1	0.44930	0.10693	4.20	<.0001	8.06258
CubQ9		1	-0.00672	0.00166	-4.06	0.0001	4.60541
CubQ10		1	0.00730	0.00190	3.83	0.0002	5.73368
CubQ11		1	0.00413	0.00162	2.55	0.0123	3.89675
LogQ4		1	-1.63290	0.37112	-4.40	<.0001	5.48924
LogQ7		1	-0.55153	0.19397	-2.84	0.0055	4.02678

Correlation of Estimates

Variable	Label	Intercept	Q3	CubQ9
Intercept	Intercept	1.0000	-0.1254	0.2200
Q3	Faculty Member Gave assignments related to the goals of this course	-0.1254	1.0000	-0.4544
CubQ9		0.2200	-0.4544	1.0000
CubQ10		0.3782	-0.1128	-0.2045
CubQ11		0.1779	0.1131	-0.2513
LogQ4		-0.7188	-0.4875	0.1289
LogQ7		-0.0441	-0.3478	-0.0124

Correlation of Estimates

Variable	Label	CubQ10	CubQ11	LogQ4
Intercept	Intercept	0.3782	0.1779	-0.7188
Q3	Faculty Member Gave assignments related to the goals of this course	-0.1128	0.1131	-0.4875
CubQ9		-0.2045	-0.2513	0.1289

Model with Transformations: Q3 CubQ9 CubQ10 CubQ11 LogQ4 LogQ7 in

The REG Procedure
Model: MODEL1
Dependent Variable: logy

Correlation of Estimates

Variable	Label	CubQ10	CubQ11	LogQ4
CubQ10		1.0000	-0.3639	-0.1654
CubQ11		-0.3639	1.0000	-0.2995
LogQ4		-0.1654	-0.2995	1.0000
LogQ7		-0.2606	-0.0079	-0.0717

Correlation of Estimates

Variable	Label	LogQ7
Intercept	Intercept	-0.0441
Q3	Faculty Member Gave assignments related to the goals of this course	-0.3478
CubQ9		-0.0124
CubQ10		-0.2606
CubQ11		-0.0079
LogQ4		-0.0717
LogQ7		1.0000

Collinearity Diagnostics

Number	Eigenvalue	Condition Index
1	6.90684	1.00000
2	0.06103	10.63785
3	0.01508	21.40105
4	0.01068	25.43105
5	0.00414	40.85658
6	0.00149	68.12190
7	0.00073867	96.69758

Collinearity Diagnostics

	Proportion of Variation						
Number	Intercept	Q3	CubQ9	CubQ10	CubQ11	LogQ4	LogQ7
1	0.00005372	0.00003051	0.00033038	0.00024346	0.00030273	0.00002200	0.00009633
2	0.01380	0.00092710	0.06196	0.03556	0.02392	0.00178	0.00147
3	0.00015348	0.00139	0.55863	0.05594	0.37823	0.00004086	0.00059860
4	0.00190	0.00024234	0.11233	0.55887	0.49388	0.00004426	0.02230
5	0.08176	0.00000210	0.03072	0.24949	0.01951	0.00924	0.81912
6	0.50226	0.57800	0.19082	0.07636	0.00199	0.03570	0.14837
7	0.40008	0.41941	0.04521	0.02354	0.08217	0.95317	0.00804

Model with Transformations: Q3 CubQ9 CubQ10 CubQ11 LogQ4 LogQ7 in

The REG Procedure
Model: MODEL1
Dependent Variable: logy

Collinearity Diagnostics (intercept adjusted)

		Condition	Proportion of Variation					
Number	Eigenvalue	Index	Q3	CubQ9	CubQ10	CubQ11	LogQ4	LogQ7
1	5.03765	1.00000	0.00437	0.00704	0.00603	0.00797	0.00611	0.00787
2	0.30217	4.08310	0.03848	0.00252	0.01137	0.46326	0.00068609	0.27650
3	0.23724	4.60813	0.00752	0.62676	0.00307	0.04600	0.15417	0.05586
4	0.19995	5.01942	0.07418	0.00384	0.06317	0.07007	0.38021	0.41305
5	0.13890	6.02230	0.00267	0.02169	0.91560	0.30770	0.00030824	0.15583
6	0.08410	7.73955	0.87278	0.33815	0.00075523	0.10500	0.45852	0.0908

Appendix M : Validation Data with the Validation Sample for the Model with Variable Transformation

CourseId	Observed Course Grade Average	Log of Observed Course Grade Average	Q3	CubQ9	CubQ10	CubQ11	LogQ4	LogQ7	Predicted Course Grade Average	Residuals
5	2.96	1.0742487	4.7000000	90.0815942	95.2352963	103.1389561	1.5187835	1.3862944	2.9277923	0.0283053
11	3.21	0.9647794	4.0689655	57.3848397	65.6694821	78.1755710	1.3948781	1.2576770	2.6242086	0.5893049
13	3.07	0.9071697	3.6250000	58.0040952	73.4284668	78.4714661	1.4094614	1.0546492	2.4773012	0.5924663
17	2.72	0.6943495	4.0000000	92.9234683	72.8497863	82.4799512	1.4152819	1.3256697	2.0024061	0.7186466
20	2.12	0.7886975	4.2285714	86.8542274	77.1533294	77.1533294	1.4282586	1.3934118	2.2005283	-0.0772725
23	2.60	0.8951787	4.2187500	71.5516877	71.3215194	85.8691227	1.4842748	1.2010273	2.4477733	0.1522267
25	3.05	0.8330926	4.3600000	95.8784137	79.9344561	98.3158853	1.4954937	1.3062517	2.3004221	0.7529112
26	2.91	0.7798162	3.6111111	48.5096682	40.8655693	17.3384897	1.2527630	0.9650809	2.1810712	0.7276244
27	2.70	0.9044200	4.2142857	79.9344561	86.8542274	91.1250000	1.4880771	1.3121864	2.4704985	0.2340470
28	2.43	0.7680185	4.3225806	69.2818422	74.0880000	35.1541679	1.5004867	1.1526795	2.1554909	0.2695091
31	2.10	0.9406516	4.6666667	110.5920000	111.2515927	114.0841250	1.5606477	1.5214691	2.5616500	-0.4584242
40	2.44	0.7626325	4.3043478	82.0947315	75.5406649	89.8107175	1.4868356	1.4604023	2.1439126	0.2971131
41	2.21	0.9637095	3.9411765	49.2962963	61.3701989	72.8497863	1.3862944	1.1826954	2.6214025	-0.4094025
43	2.57	0.7886476	4.2173913	75.5406649	71.4733750	86.4125966	1.4796263	1.3643155	2.2004186	0.3662481
44	2.11	0.8125044	2.7857143	17.5760000	33.2088192	31.3705052	1.1837701	0.8183103	2.2535447	-0.1405012
48	1.47	0.7132440	4.2631579	80.3860621	74.6464499	77.4808281	1.4982123	1.3993664	2.0406003	-0.5681865
51	1.88	0.7172455	4.3500000	92.7330515	79.5070000	97.3360000	1.5368672	1.4109870	2.0487822	-0.1737822
52	2.08	0.6635103	4.2777778	84.5402949	75.2702332	81.3703704	1.5040774	1.4708517	1.9415959	0.1353272
57	2.16	0.6735704	4.6666667	99.8973440	57.1490118	104.0686379	1.5561934	1.3581235	1.9612272	0.2003113
60	2.44	0.7842019	4.0000000	114.5889213	95.5335277	114.5889213	1.4213857	1.4213857	2.1906579	0.2493421
67	3.33	0.8556098	3.7619048	49.2962963	49.2962963	57.3848397	1.3499267	1.0647107	2.3528087	0.9805246
69	2.90	1.1212507	3.2857143	31.0437318	49.2962963	48.6271250	1.1895841	0.8266786	3.0686898	-0.1686898
70	2.97	0.8991656	3.9642857	65.7942895	72.9597759	76.7656250	1.3955110	1.2729657	2.4575518	0.5074482
71	2.75	0.7397596	4.3076923	94.8188160	88.8083751	93.4815658	1.5210270	1.4514337	2.0954317	0.6571999
73	2.69	0.7589919	4.2962963	69.6997610	54.2554665	77.2684550	1.4880771	1.2321437	2.1361218	0.5569015
75	2.41	1.0102966	4.8571429	104.7725948	111.2515927	111.2515927	1.5705981	1.5705981	2.7464155	-0.3373245
82	3.55	0.8276889	4.2903226	90.1486691	86.3130811	97.3360000	1.5218399	1.3281867	2.2880248	1.2619752
86	3.15	0.7656648	4.6470588	85.8691227	58.1855469	96.5910849	1.5488133	1.3256697	2.1504236	0.9945764
87	2.60	1.0376799	3.9285714	51.2419825	67.4901603	86.8542274	1.4384801	1.0459686	2.8226607	-0.2226607
88	2.42	0.9521852	4.1666667	72.3379630	83.7402344	88.6171152	1.4350845	1.3762440	2.5913662	-0.1729452
89	2.45	0.9464392	4.5000000	73.4284668	77.6722963	91.1250000	1.5178707	1.3382851	2.5765189	-0.1231855
91	2.97	0.9134328	4.4516129	84.4367762	84.4367762	92.1083549	1.4932665	1.3943265	2.4928653	0.4754274
98	3.00	0.7556894	4.1724138	59.1617943	64.0000000	66.2067055	1.4689861	1.3682759	2.1290788	0.8685956
100	2.64	0.9889730	4.4285714	71.1049563	82.7190233	91.1250000	1.4880771	1.3862944	2.6884720	-0.0456149
108	1.89	0.8160619	4.1621622	77.8692674	72.3379630	69.3307010	1.4325072	1.2642794	2.2615759	-0.3680976
109	2.26	0.7074268	4.0740741	75.2702332	65.7296374	78.7172012	1.4384801	1.3862944	2.0287641	0.2322115
115	3.39	0.8999382	4.3076923	86.1556713	84.2935822	93.4815658	1.4604023	1.3862944	2.4594510	0.9300227
117	2.52	0.6886887	4.1764706	85.8691227	82.4799512	75.9715042	1.4975200	1.4008932	1.9911028	0.5238972
118	2.36	0.9386566	4.1764706	66.8652554	73.4284668	83.7402344	1.4434528	1.2776605	2.5565445	-0.1982112
122	2.13	0.6871018	4.2105263	66.5597026	50.6530000	50.6530000	1.4122698	1.3083328	1.9879458	0.1389773
125	2.42	0.7146918	3.2857143	48.3422012	35.4723032	51.2419825	1.3121864	0.8266786	2.0435569	0.3714431
131	2.80	0.9118089	3.8823529	79.1811520	85.8691227	82.4799512	1.3862944	1.2611312	2.4888204	0.3070129
132	2.44	0.6373486	4.1111111	94.5418381	64.0000000	70.1894531	1.4403616	1.2163953	1.8914592	0.5438350
135	2.86	1.5224278	4.6666667	125.0000000	125.0000000	125.0000000	1.2527630	1.4663371	4.5833391	-1.7233391
137	2.54	0.8409467	4.0000000	51.7813674	64.0000000	64.0000000	1.4069136	1.3304139	2.3185610	0.2223481
138	2.73	0.8592903	4.3750000	93.1650370	98.3158853	103.3140646	1.5448994	1.4384801	2.3614843	0.3670872
139	2.97	0.6716916	3.6000000	37.0370370	49.2962963	64.0000000	1.4087672	1.2909842	1.9575459	1.0112041
142	3.07	1.0901038	4.6153846	98.3158853	108.4788348	112.9120370	1.5293952	1.4053426	2.9745827	0.0968459
144	2.30	1.0154309	4.7500000	111.8534936	111.8534936	118.3050338	1.5581446	1.4853853	2.7605528	-0.4605528
153	2.64	0.8063025	4.0000000	73.7471048	71.5516877	76.3558450	1.4246132	1.2656664	2.2396117	0.4003883

Appendix N: Table of Actual Proportion of Faculty High Performance and Predicted Probability of Faculty High Performance

Course Section	Course ID	Q9	Q11	Q16	Math	Actual High Performance Score	Actual High Performance Indicator	Predicted High Performance Score	Predicted High Performance Indicator	Concordance Indicator
0099	2	3.8214	3.9643	3.3913	0	0.2174	0	0.8423	1	0
0099	3	4.4583	4.6538	4.4737	0	0.6176	1	0.9850	1	1
1070	4	4.3750	4.7917	4.3000	0	0.4146	1	0.9881	1	1
1070	6	4.0000	4.2857	3.9444	0	0.5833	1	0.9604	1	1
1070	7	4.2593	4.6667	4.0769	0	0.7143	1	0.9804	1	1
1070	8	4.2273	4.4783	3.5455	0	0.4103	1	0.9235	1	1
1070	9	4.7742	4.8710	4.4194	0	0.5714	1	0.9821	1	1
1070	10	4.3448	4.5333	4.1111	0	0.9545	1	0.9687	1	1
1070	12	3.3500	3.8182	2.2500	0	0.9474	1	0.5451	1	1
1070	14	3.8462	3.4286	3.2857	0	0.6512	1	0.4931	1	1
1070	15	4.6000	4.7200	4.3913	0	0.5556	1	0.9804	1	1
1070	16	4.4839	4.5484	4.3793	0	0.6053	1	0.9752	1	1
1070	63	4.5667	4.6897	4.3333	0	0.7143	1	0.9780	1	1
1070	64	4.3846	4.5000	4.0357	0	0.5854	1	0.9576	1	1
1070	65	4.4688	4.5938	4.0333	0	0.7273	1	0.9604	1	1
1070	66	3.9048	4.2381	3.2105	0	0.7632	1	0.8709	1	1
1070	72	4.2941	4.2941	4.0667	0	0.5952	1	0.9431	1	1
1070	80	4.5357	4.3214	3.7692	0	0.6585	1	0.8605	1	1
1070	107	4.2500	4.4643	3.9231	0	0.5897	1	0.9569	1	1
1070	110	3.6667	4.0000	3.2000	0	0.8611	1	0.8520	1	1
1070	145	4.0606	3.8857	3.4333	0	0.4651	1	0.7368	1	1
1101	18	4.0667	3.8571	3.1111	0	0.5682	1	0.5855	1	1
1101	19	4.5455	4.6286	3.5357	0	0.4186	1	0.9005	1	1
1101	21	4.4706	4.6316	4.2222	0	0.5600	1	0.9743	1	1
1101	22	4.8800	4.9167	4.3182	0	0.7188	1	0.9762	1	1
1101	24	4.7143	4.7619	3.6667	0	0.5217	1	0.9203	1	1
1101	29	4.5000	4.2500	3.7000	0	0.4545	1	0.8283	1	1
1101	30	4.9500	4.8500	4.8000	0	0.4545	1	0.9862	1	1
1101	74	3.8667	4.1429	3.3077	0	0.3939	0	0.8711	1	0
1101	83	4.9333	4.7333	3.1818	0	0.7391	1	0.7328	1	1
1101	84	4.5000	4.5714	3.9444	0	0.4595	1	0.9477	1	1
1101	85	4.1875	4.5625	3.1429	0	0.6667	1	0.8873	1	1
1101	92	4.6923	4.2857	3.1000	0	0.2273	0	0.5388	1	0
1101	93	4.3333	4.3333	3.7667	0	0.3409	0	0.9071	1	0
1101	94	4.3810	3.8095	3.5556	0	0.3636	0	0.5901	1	0
1101	103	4.3462	4.5517	4.2609	0	0.5238	1	0.9771	1	1
1101	104	4.2759	4.6552	4.0000	0	0.6818	1	0.9760	1	1
1101	105	4.4375	4.8824	3.8333	0	0.6087	1	0.9752	1	1
1101	106	4.1765	4.2353	3.1538	0	0.3182	0	0.7716	1	0
1101	111	4.3000	4.1000	3.0000	0	0.8571	1	0.5752	1	1
1101	112	4.2941	4.5882	4.0667	0	0.8571	1	0.9736	1	1
1101	116	4.2941	4.4000	3.8148	0	0.5897	1	0.9329	1	1
1101	119	4.6875	4.6000	4.1538	0	0.5652	1	0.9508	1	1
1101	120	4.2353	4.2941	3.9375	0	0.6522	1	0.9368	1	1
1101	121	4.3846	4.8462	4.3636	0	0.4500	1	0.9906	1	1
1101	123	4.1250	4.2500	3.8750	0	0.4118	1	0.9368	1	1
1101	124	4.9375	4.8125	4.4667	0	0.6957	1	0.9729	1	1
1101	126	4.7500	4.8333	4.0909	0	0.6500	1	0.9660	1	1
1101	127	4.3077	3.3846	4.4000	0	0.5000	1	0.7154	1	1
1101	128	4.4167	4.5833	4.2500	0	0.4583	1	0.9752	1	1
1101	129	4.4000	4.8000	4.6667	0	0.5263	1	0.9937	1	1

Course Section	Course ID	Q9	Q11	Q16	Math	Actual High Performance Score	Actual High Performance Indicator	Predicted High Performance Score	Predicted High Performance Indicator	Concordance Indicator
1101	130	4.1333	4.3333	3.9231	0	0.4500	1	0.9523	1	1
1101	133	4.8333	4.8333	4.4167	0	0.4118	1	0.9774	1	1
1101	134	5.0000	5.0000	3.0000	0	0.6000	1	0.7784	1	1
1101	148	4.4500	4.4211	3.6000	0	0.5833	1	0.8767	1	1
1101	149	4.4118	4.7647	3.8571	0	0.4348	1	0.9692	1	1
1101	150	5.0000	5.0000	5.0000	0	0.6667	1	0.9929	1	1
1101	151	2.6667	3.6667	2.0000	0	0.4000	1	0.6825	1	1
1101	152	4.3333	3.6667	3.3333	0	0.2000	0	0.4178	1	0
1101	154	4.6087	4.6818	4.0000	0	0.4571	1	0.9556	1	1
1101	155	4.3043	4.3043	3.9565	0	0.5405	1	0.9316	1	1
1111	32	3.9259	4.4348	3.5652	0	0.4865	1	0.9549	1	1
1111	33	3.3333	3.8750	4.0000	0	0.5455	1	0.9733	1	1
1111	34	4.1176	4.5882	3.8824	0	0.8333	1	0.9745	1	1
1111	35	4.7647	4.8000	4.6250	0	0.4054	1	0.9854	1	1
1111	36	4.2667	4.6154	4.1111	0	0.6000	1	0.9786	1	1
1111	37	3.4286	3.6000	2.6000	0	0.6667	1	0.5163	1	1
1111	68	4.5217	4.5238	4.2727	0	0.4000	1	0.9653	1	1
1111	78	4.4474	4.8000	3.5714	0	0.6739	1	0.9500	1	1
1111	95	4.5294	4.6667	4.6429	0	0.6250	1	0.9876	1	1
1111	96	4.4286	4.7143	4.2000	0	0.8667	1	0.9803	1	1
1111	97	4.4815	4.6957	3.8000	0	0.6053	1	0.9530	1	1
1111	99	4.2000	4.1111	3.2941	0	0.6364	1	0.7481	1	1
1111	136	4.5556	4.8750	4.6667	0	0.7500	1	0.9929	1	1
1111	140	4.0000	4.2727	2.9091	0	0.4500	1	0.7764	1	1
1111	141	4.4667	4.7333	4.3077	0	0.5909	1	0.9833	1	1
1113	38	3.8125	4.1667	3.9333	0	0.3429	0	0.9624	1	0
1113	39	4.3810	4.2778	4.0000	0	0.4000	1	0.9210	1	1
1113	42	4.3600	4.6000	4.1538	0	0.6216	1	0.9749	1	1
1113	76	4.0435	4.4211	3.3889	0	0.3714	0	0.9198	1	0
1113	77	3.1429	4.1667	2.9048	0	0.4048	1	0.9414	1	1
1113	90	2.1667	3.3333	2.1111	0	0.3333	0	0.7559	1	0
1113	101	4.0588	4.6000	3.8750	0	0.5217	1	0.9779	1	1
1113	102	2.4000	3.1538	2.2500	0	0.4737	1	0.5989	1	1
1113	143	4.3214	4.5833	4.2727	0	0.4390	1	0.9805	1	1
1113	146	4.0714	4.6429	3.7500	0	0.5000	1	0.9746	1	1
1113	147	2.3333	3.1538	2.5000	0	0.5455	1	0.7318	1	1
2008	81	4.5000	4.6429	4.2857	1	0.4091	1	0.4146	1	1
2008	114	4.6667	4.7778	4.9375	1	0.4400	1	0.7041	1	1
2211	45	4.4286	4.2857	4.2778	1	0.2667	0	0.2354	0	1
2211	46	3.6667	3.5000	3.0000	1	0.2593	0	0.0172	0	1
2211	47	4.2308	4.3846	3.5000	1	0.2222	0	0.1278	0	1
2211	49	4.3000	4.5000	3.6111	1	0.1250	0	0.1751	0	1
2211	50	4.7000	4.6842	4.4000	1	0.1739	0	0.3897	0	1
2211	53	4.4737	4.0500	4.0588	1	0.1333	0	0.0896	0	1
2211	54	4.4400	4.4231	4.2308	1	0.1471	0	0.2858	0	1
2212	55	4.6071	4.1481	4.4583	1	0.1765	0	0.1680	0	1
2212	56	4.5769	4.5385	4.0435	1	0.2632	0	0.2246	0	1
2212	79	4.7895	4.6316	4.3125	1	0.1818	0	0.2802	0	1
2212	113	4.3158	4.3889	3.3125	1	0.2222	0	0.0805	0	1
2215	58	4.4815	4.5714	4.4400	1	0.4412	1	0.4463	1	1
2215	59	4.3636	4.3077	4.5000	1	0.5263	1	0.3611	0	0
1070	5	4.4828	4.6897	4.1154	0	0.6098	1	0.9726	1	1

Course Section	Course ID	Q9	Q11	Q16	Math	Actual High Performance Score	Actual High Performance Indicator	Predicted High Performance Score	Predicted High Performance Indicator	Concordance Indicator
1070	11	3.8571	4.2759	3.9200	0	0.6486	1	0.9683	1	1
1070	13	3.8710	4.2813	3.1379	0	0.6977	1	0.8770	1	1
1101	17	4.5294	4.3529	3.4375	0	0.5789	1	0.7871	1	1
1101	20	4.4286	4.2571	3.5152	0	0.2558	0	0.8030	1	0
1101	23	4.1515	4.4118	3.5455	0	0.5385	1	0.9221	1	1
1101	25	4.5769	4.6154	3.6522	0	0.7111	1	0.9101	1	1
1101	26	3.6471	2.5882	2.7857	0	0.5652	1	0.0569	0	0
1101	27	4.3077	4.5000	3.7273	0	0.5909	1	0.9378	1	1
1101	28	4.1071	3.2759	3.3462	0	0.3250	0	0.2916	0	1
1101	31	4.8000	4.8500	4.5500	0	0.3548	0	0.9842	1	0
1113	40	4.3462	4.4783	4.1364	0	0.4359	1	0.9653	1	1
1113	41	3.6667	4.1765	3.4667	0	0.3600	0	0.9383	1	0
1113	43	4.2273	4.4211	3.5238	0	0.5238	1	0.9085	1	1
1113	44	2.6000	3.1538	2.4167	0	0.3913	0	0.5699	1	0
2211	48	4.3158	4.2632	4.3125	1	0.2069	0	0.2819	0	1
2211	51	4.5263	4.6000	3.7222	1	0.1875	0	0.1742	0	1
2211	52	4.3889	4.3333	4.4615	1	0.3462	0	0.3485	0	1
2212	57	4.6400	4.7037	4.0435	1	0.3590	0	0.2840	0	1
2215	60	4.8571	4.8571	3.5714	1	0.5000	1	0.1370	0	0
1101	67	3.6667	3.8571	3.0500	0	0.8333	1	0.7475	1	1
1101	69	3.1429	3.6500	2.3500	0	0.5833	1	0.5865	1	1
1070	70	4.0370	4.2500	3.6786	0	0.6500	1	0.9256	1	1
1070	71	4.5600	4.5385	4.1600	0	0.5263	1	0.9560	1	1
1070	73	4.1154	4.2593	3.6923	0	0.6279	1	0.9172	1	1
1101	75	4.7143	4.8095	4.5000	0	0.3939	0	0.9839	1	0
2008	82	4.4839	4.6000	4.3448	1	0.8500	1	0.4211	1	1
1101	86	4.4118	4.5882	3.3571	0	0.7000	1	0.8859	1	1
1101	87	3.7143	4.4286	3.5385	0	0.5000	1	0.9688	1	1
1111	88	4.1667	4.4583	4.1579	0	0.3947	0	0.9757	1	0
1111	89	4.1875	4.5000	3.7143	0	0.4000	1	0.9501	1	1
1070	91	4.3871	4.5161	4.1000	0	0.6585	1	0.9636	1	1
1111	98	3.8966	4.0455	3.6000	0	0.7209	1	0.8929	1	1
1113	100	4.1429	4.5000	3.8182	0	0.5714	1	0.9620	1	1
0099	108	4.2703	4.1081	3.5172	0	0.2609	0	0.7927	1	0
1070	109	4.2222	4.2857	4.0000	0	0.4146	1	0.9435	1	1
1070	115	4.4167	4.5385	3.7692	0	0.7895	1	0.9348	1	1
1101	117	4.4118	4.2353	4.0000	0	0.3500	0	0.9068	1	0
1101	118	4.0588	4.3750	3.3846	0	0.6250	1	0.9066	1	1
1101	122	4.0526	3.7000	3.7059	0	0.3462	0	0.7396	1	0
1101	125	3.6429	3.7143	2.3636	0	0.5000	1	0.3736	0	0
1101	131	4.2941	4.3529	3.8750	0	0.6250	1	0.9318	1	1
1101	132	4.5556	4.1250	3.8889	0	0.4118	1	0.8121	1	1
1101	135	5.0000	5.0000	4.0000	0	0.6000	1	0.9568	1	1
1111	137	3.7273	4.0000	3.3750	0	0.4318	1	0.8747	1	1
1111	138	4.5333	4.6923	4.0909	0	0.5714	1	0.9685	1	1
1111	139	3.3333	4.0000	3.2000	0	0.6250	1	0.9214	1	1
1111	142	4.6154	4.8333	4.0769	0	0.7143	1	0.9736	1	1
1111	144	4.8182	4.9091	4.5556	0	0.3500	0	0.9861	1	0
1101	153	4.1935	4.2424	3.6667	0	0.5556	1	0.8952	1	1

Appendix O : Output of the SAS Code for Logistic Model Development

```
LOGISTIC REGRESSION MODEL WITH CATEGORICAL VARIABLE FOR HIGH PERFORMANCE OVER 40%

The LOGISTIC Procedure

                Model Information

Data Set                      THESIS.DEVSAMPSTRAT
Response Variable             hp40
Number of Response Levels     2
Model                         binary logit
Optimization Technique        Fisher's scoring

                            Model Information


Indicator of High Performance Above 40%, hp40=1 if hperf>=0.4, else hp40=0





Number of Observations Read         102
Number of Observations Used         102


          Response Profile

 Ordered                      Total
   Value         hp40     Frequency

       1            1            81
       2            0            21

Probability modeled is hp40=1.


Backward Elimination Procedure

Step  0. The following effects were entered:

Intercept  Q1  Q2  Q3  Q4  Q5  Q6  Q7  Q8  Q9  Q10  Q11  Q12  Q13  Q14  Q15  Q16  Q17  math


                    Model Convergence Status

         Convergence criterion (GCONV=1E-8) satisfied.


         Model Fit Statistics

                             Intercept
              Intercept            and
Criterion          Only     Covariates

AIC             105.724         90.757
```

SC	108.349	140.632
-2 Log L	103.724	52.757

LOGISTIC REGRESSION MODEL WITH CATEGORICAL VARIABLE FOR HIGH PERFORMANCE OVER 40%

The LOGISTIC Procedure

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	50.9665	18	<.0001
Score	46.8737	18	0.0002
Wald	19.9346	18	0.3365

Step 1. Effect Q12 is removed:

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	105.724	88.760
SC	108.349	136.009
-2 Log L	103.724	52.760

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	50.9641	17	<.0001
Score	46.8719	17	0.0001
Wald	20.0003	17	0.2742

Residual Chi-Square Test

Chi-Square	DF	Pr > ChiSq
0.0024	1	0.9611

Step 2. Effect Q1 is removed:

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

LOGISTIC REGRESSION MODEL WITH CATEGORICAL VARIABLE FOR HIGH PERFORMANCE OVER 40%

The LOGISTIC Procedure

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	105.724	86.775
SC	108.349	131.399
-2 Log L	103.724	52.775

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	50.9492	16	<.0001
Score	46.7484	16	<.0001
Wald	20.0223	16	0.2192

Residual Chi-Square Test

Chi-Square	DF	Pr > ChiSq
0.0172	2	0.9914

Step 3. Effect Q3 is removed:

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	105.724	84.803
SC	108.349	126.803
-2 Log L	103.724	52.803

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	50.9203	15	<.0001
Score	46.7247	15	<.0001
Wald	20.2228	15	0.1636

LOGISTIC REGRESSION MODEL WITH CATEGORICAL VARIABLE FOR HIGH PERFORMANCE OVER 40%

The LOGISTIC Procedure

Residual Chi-Square Test

Chi-Square	DF	Pr > ChiSq
0.0458	3	0.9974

Step 4. Effect Q5 is removed:

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	105.724	82.850
SC	108.349	122.224
-2 Log L	103.724	52.850

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	50.8742	14	<.0001
Score	46.7046	14	<.0001
Wald	20.1951	14	0.1241

Residual Chi-Square Test

Chi-Square	DF	Pr > ChiSq
0.0916	4	0.9990

Step 5. Effect Q13 is removed:

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

LOGISTIC REGRESSION MODEL WITH CATEGORICAL VARIABLE FOR HIGH PERFORMANCE OVER 40%

The LOGISTIC Procedure

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	105.724	81.098
SC	108.349	117.848
-2 Log L	103.724	53.098

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	50.6258	13	<.0001
Score	46.6365	13	<.0001
Wald	20.1965	13	0.0904

Residual Chi-Square Test

Chi-Square	DF	Pr > ChiSq
0.3404	5	0.9968

Step 6. Effect Q10 is removed:

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	105.724	79.412
SC	108.349	113.537
-2 Log L	103.724	53.412

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	50.3114	12	<.0001
Score	46.4864	12	<.0001

Wald	20.4324	12	0.0593

LOGISTIC REGRESSION MODEL WITH CATEGORICAL VARIABLE FOR HIGH PERFORMANCE OVER 40%

The LOGISTIC Procedure

Residual Chi-Square Test

Chi-Square	DF	Pr > ChiSq
0.6484	6	0.9955

Step 7. Effect Q7 is removed:

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	105.724	77.782
SC	108.349	109.282
-2 Log L	103.724	53.782

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	49.9419	11	<.0001
Score	45.9000	11	<.0001
Wald	20.0806	11	0.0442

Residual Chi-Square Test

Chi-Square	DF	Pr > ChiSq
0.9914	7	0.9950

Step 8. Effect Q6 is removed:

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

LOGISTIC REGRESSION MODEL WITH CATEGORICAL VARIABLE FOR HIGH PERFORMANCE OVER 40%

The LOGISTIC Procedure

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	105.724	76.505
SC	108.349	105.380
-2 Log L	103.724	54.505

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	49.2188	10	<.0001
Score	45.8879	10	<.0001
Wald	21.1736	10	0.0199

Residual Chi-Square Test

Chi-Square	DF	Pr > ChiSq
1.7316	8	0.9882

Step 9. Effect Q8 is removed:

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	105.724	75.231
SC	108.349	101.480
-2 Log L	103.724	55.231

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	48.4932	9	<.0001

Score	45.6980	9	<.0001
Wald	21.6807	9	0.0099

LOGISTIC REGRESSION MODEL WITH CATEGORICAL VARIABLE FOR HIGH PERFORMANCE OVER 40%

The LOGISTIC Procedure

Residual Chi-Square Test

Chi-Square	DF	Pr > ChiSq
2.5030	9	0.9808

Step 10. Effect Q17 is removed:

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	105.724	73.882
SC	108.349	97.507
-2 Log L	103.724	55.882

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	47.8413	8	<.0001
Score	44.8472	8	<.0001
Wald	21.0400	8	0.0070

Residual Chi-Square Test

Chi-Square	DF	Pr > ChiSq
3.2097	10	0.9760

Step 11. Effect Q15 is removed:

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

LOGISTIC REGRESSION MODEL WITH CATEGORICAL VARIABLE FOR HIGH PERFORMANCE OVER 40%

The LOGISTIC Procedure

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	105.724	74.152
SC	108.349	95.152
-2 Log L	103.724	58.152

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	45.5720	7	<.0001
Score	44.0125	7	<.0001
Wald	23.1423	7	0.0016

Residual Chi-Square Test

Chi-Square	DF	Pr > ChiSq
5.3461	11	0.9133

Step 12. Effect Q4 is removed:

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	105.724	74.558
SC	108.349	92.933
-2 Log L	103.724	60.558

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq

Likelihood Ratio	43.1655	6	<.0001
Score	43.0299	6	<.0001
Wald	23.7064	6	0.0006

LOGISTIC REGRESSION MODEL WITH CATEGORICAL VARIABLE FOR HIGH PERFORMANCE OVER 40%

The LOGISTIC Procedure

Residual Chi-Square Test

Chi-Square	DF	Pr > ChiSq
7.0134	12	0.8567

Step 13. Effect Q2 is removed:

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	105.724	74.103
SC	108.349	89.853
-2 Log L	103.724	62.103

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	41.6210	5	<.0001
Score	41.9338	5	<.0001
Wald	22.8217	5	0.0004

Residual Chi-Square Test

Chi-Square	DF	Pr > ChiSq
8.0351	13	0.8413

Step 14. Effect Q14 is removed:

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

LOGISTIC REGRESSION MODEL WITH CATEGORICAL VARIABLE FOR HIGH PERFORMANCE OVER 40%

The LOGISTIC Procedure

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	105.724	73.075
SC	108.349	86.199
-2 Log L	103.724	63.075

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	40.6492	4	<.0001
Score	41.0848	4	<.0001
Wald	22.2235	4	0.0002

Residual Chi-Square Test

Chi-Square	DF	Pr > ChiSq
8.7669	14	0.8457

NOTE: No (additional) effects met the 0.05 significance level for removal from the model.

Summary of Backward Elimination

Step	Effect Removed	DF	Number In	Wald Chi-Square	Pr > ChiSq	Variable Label
1	Q12	1	17	0.0024	0.9611	Faculty Member Met the class according to the published Schedule of Classes
2	Q1	1	16	0.0149	0.9028	Faculty Member Explained the goals of this course clearly
3	Q3	1	15	0.0286	0.8657	Faculty Member Gave assignments related to the goals of this course
4	Q5	1	14	0.0462	0.8299	Faculty Member Was well prepared
5	Q13	1	13	0.2487	0.6180	Faculty Member Stimulated my thinking and gave me new insights into the subject
6	Q10	1	12	0.3054	0.5805	Faculty Member Assigned grades fairly
7	Q7	1	11	0.3643	0.5461	Faculty Member Responded constructively and thoughtfully to questions and comments
8	Q6	1	10	0.7141	0.3981	Faculty Member Spoke in a way that communicated the subject in an understandable manner
9	Q8	1	9	0.7222	0.3954	Faculty Member Used class time effectively
10	Q17	1	8	0.6249	0.4292	Considering both the limitations and possibilities of the subject matter and course, how would you rate the overall teaching effectiveness of the instructor?
11	Q15	1	7	2.0680	0.1504	Faculty Member Motivated me to learn
12	Q4	1	6	2.1527	0.1423	Faculty Member Followed the plan for the course as established in the syllabus
13	Q2	1	5	1.2995	0.2543	Faculty Member Explained the grading system clearly
14	Q14	1	4	0.9340	0.3338	Faculty Member Related well to students

LOGISTIC REGRESSION MODEL WITH CATEGORICAL VARIABLE FOR HIGH PERFORMANCE OVER 40%

The LOGISTIC Procedure

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-7.1988	3.1392	5.2587	0.0218
Q9	1	-2.1322	0.9626	4.9060	0.0268
Q11	1	2.7178	1.1402	5.6812	0.0171
Q16	1	1.8425	0.7856	5.5007	0.0190
math	1	-4.0660	0.9286	19.1708	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
Q9	0.119	0.018	0.782
Q11	15.146	1.621	141.540
Q16	6.312	1.354	29.436
math	0.017	0.003	0.106

Association of Predicted Probabilities and Observed Responses

Percent Concordant	89.2	Somers' D	0.784
Percent Discordant	10.8	Gamma	0.785
Percent Tied	0.1	Tau-a	0.259
Pairs	1701	c	0.892

Wald Confidence Interval for Odds Ratios

Effect	Unit	Estimate	95% Confidence Limits	
Q9	1.0000	0.119	0.018	0.782
Q11	1.0000	15.146	1.621	141.540
Q16	1.0000	6.312	1.354	29.436
math	1.0000	0.017	0.003	0.106

Partition for the Hosmer and Lemeshow Test

		hp40 = 1		hp40 = 0	
Group	Total	Observed	Expected	Observed	Expected
1	10	0	1.68	10	8.32
2	10	7	4.70	3	5.30
3	10	9	6.83	1	3.17
4	10	6	8.21	4	1.79
5	10	8	9.12	2	0.88
6	10	10	9.47	0	0.53

7	10	9	9.62	1	0.38
8	10	10	9.74	0	0.26
9	10	10	9.78	0	0.22
10	12	12	11.85	0	0.15

The LOGISTIC Procedure

Hosmer and Lemeshow Goodness-of-Fit Test

Chi-Square	DF	Pr > ChiSq
13.4817	8	0.0963

Classification Table

	Correct		Incorrect		Percentages				
Prob Level	Event	Non-Event	Event	Non-Event	Correct	Sensi-tivity	Speci-ficity	False POS	False NEG
0.200	81	6	15	0	85.3	100.0	28.6	15.6	0.0
0.300	80	8	13	1	86.3	98.8	38.1	14.0	11.1
0.400	78	10	11	3	86.3	96.3	47.6	12.4	23.1
0.500	74	12	9	7	84.3	91.4	57.1	10.8	36.8
0.600	71	12	9	10	81.4	87.7	57.1	11.3	45.5
0.700	67	14	7	14	79.4	82.7	66.7	9.5	50.0
0.800	63	15	6	18	76.5	77.8	71.4	8.7	54.5

The FREQ Procedure

Table of hp40 by pred_hp40 in Development Sample

hp40(Indicator of High Performance Above 40%, hp40=1 if hperf>=0.4, else hp40=0)
pred_hp40

Frequency Percent	0	1	Total
0	11 10.78	10 9.80	21 20.59
1	1 0.98	80 78.43	81 79.41
Total	12 11.76	90 88.24	102 100.00

LOGISTIC REGRESSION MODEL WITH CATEGORICAL VARIABLE FOR HIGH PERFORMANCE OVER 40%

The FREQ Procedure

Table of act_hp40 by pred_hp40 in Validation Sample

act_hp40(Indicator of High Performance Above 40%%, hp40=1 if hperf>=0.4, else hp40=0)
pred_hp40

Frequency Percent	0	1	Total
0	5 10.00	10 20.00	15 30.00
1	3 6.00	32 64.00	35 70.00
Total	8 16.00	42 84.00	50 100.00

The FREQ Procedure

Table of act_hp40 by pred_hp40 in Whole Sample

act_hp40(Indicator of High Performance Above 40%%, hp40=1 if hperf>=0.4, else hp40=0)
pred_hp40

Frequency Percent	0	1	Total
0	16 10.53	20 13.16	36 23.68
1	4 2.63	112 73.68	116 76.32
Total	20 13.16	132 86.84	152 100.00

Appendix P : SAS Code

```
/* --------------------------------------------------------------
   File name: Studgrade_and_SEF_by_CourseID_Fall2009.sas
   Code to Reformat The Student Grade & SEF Dataset
   Build Development and Validation Samples and
   Apply various Techniques to Data Analysis
   To study relationship between SEF and Faculty Teaching
   Effectiveness (Faculty Performance)
--------------------------------------------------------------*/

options LINESIZE=120 PAGESIZE=60 nonumber nodate nocenter;
%let dts=C:\Users\Etienne\Documents\GSU\Thesis_Docs\;
libname thesis "&dts";

%let msef= Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12 Q13 Q14 Q15 Q16 Q17;
%let grad_dist=Aplus A Aminus Bplus B Bminus Cplus C Cminus D F;
%let grad_dist_list=Aplus, A, Aminus, Bplus, B, Bminus, Cplus, C, Cminus, D,
F;
%let grad_percent_dist=Aplus_pct A_pct Aminus_pct Bplus_pct B_pct Bminus_pct
Cplus_pct C_pct Cminus_pct D_pct F_pct;
%let grad_percent_list=Aplus_pct, A_pct, Aminus_pct, Bplus_pct, B_pct,
Bminus_pct, Cplus_pct, C_pct, Cminus_pct, D_pct, F_pct;
%let pvalue=0.05;

data thesis.Studgrade_and_sef_by_cseid_f09;
   attrib sec format=$4.;
   length courseid grade_avg sef_avg studno 8.;
   attrib courseid format=4.;
   attrib grade_avg format=4.2;
   attrib sef_avg format=4.2;
   attrib studno format=4.;
   attrib Q1-Q17 format=5.3;
   attrib &grad_dist format=4.;
   length gradelevel $6.;
   length &grad_percent_dist 5.2;
   set thesis.StudGrade_and_CourseEval (drop= avg_grade avg_eval);
   sef_avg=mean(Q1,Q2,Q3,Q4,Q5,Q6,Q7,Q8,Q9,Q10,Q11,Q12,Q13,Q14,Q15,Q16,Q17);
   grade_avg=sum(4.3*Aplus,4.0*A,3.7*Aminus,
3.3*Bplus,3.0*B,2.7*Bminus,2.3*Cplus,2.0*C,1.7*Cminus,1.0*D,0*F)/
      sum(Aplus,A,Aminus,Bplus,B,Bminus,Cplus,C,Cminus,D,F);
   studno = sum(Aplus,A,Aminus,Bplus,B,Bminus,Cplus,C,Cminus,D,F);

   label  Q1='Faculty Member Explained the goals of this course clearly';
   label  Q2='Faculty Member Explained the grading system clearly';
   label  Q3='Faculty Member Gave assignments related to the goals of this
course';
   label  Q4='Faculty Member Followed the plan for the course as established
in the syllabus';
   label  Q5='Faculty Member Was well prepared';
   label  Q6='Faculty Member Spoke in a way that communicated the subject in
an understandable manner';
   label  Q7='Faculty Member Responded constructively and thoughtfully to
questions and comments';
   label  Q8='Faculty Member Used class time effectively';
```

```
   label  Q9='Faculty Member Had designated office and student appointment
hours and was available to students during these times';
   label  Q10='Faculty Member Assigned grades fairly';
   label  Q11='Faculty Member Returned test results and evaluations of my
work in a reasonable period of time';
   label  Q12='Faculty Member Met the class according to the published
Schedule of Classes';
   label  Q13='Faculty Member Stimulated my thinking and gave me new insights
into the subject';
   label  Q14='Faculty Member Related well to students';
   label  Q15='Faculty Member Motivated me to learn';
   label  Q16='Faculty Member Assigned readings (including the text(s)) that
contributed to what I learned';
   label  Q17='Considering both the limitations and possibilities of the
subject matter and course, how would you rate the overall teaching
effectiveness of the instructor?';
   label  sec='Course Section';
   label  grade_avg='Course Grade Average Per Student';
   label  sef_avg='Course Average SEF';
   label  studno='Course Number of Students';

   /* Percentage of Students with a grade level */
   Aplus_pct=Aplus*100/studno;
   A_pct=A*100/studno;
   Aminus_pct=Aminus*100/studno;
   Bplus_pct=Bplus*100/studno;
   B_pct=B*100/studno;
   Bminus_pct=Bminus*100/studno;
   Cplus_pct=Cplus*100/studno;
   C_pct=C*100/studno;
   Cminus_pct=Cminus*100/studno;
   D_pct=D*100/studno;
   F_pct=F*100/studno;

   label Aplus_pct='Percent of Students with Aplus Grade';
   label A_pct='Percent of Students with A Grade';
   label Aminus_pct='Percent of Students with Aminus Grade';
   label Bplus_pct='Percent of Students with Bplus Grade';
   label B_pct='Percent of Students with B Grade';
   label Bminus_pct='Percent of Students with Bminus Grade';
   label Cplus_pct='Percent of Students with Cplus Grade';
   label C_pct='Percent of Students with C Grade';
   label Cminus_pct='Percent of Students with Cminus Grade';
   label D_pct='Percent of Students with D Grade';
   label F_pct='Percent of Students with F Grade';

   keep sec courseid grade_avg studno Q1-Q17 sef_avg &grad_dist;
run;

title '';
proc univariate data= thesis.Studgrade_and_sef_by_cseid_f09 ;
     var grade_avg sef_avg;
    histogram/normal;
    *qqplot;
    *probplot;
run;
```

```
proc means data= thesis.Studgrade_and_sef_by_cseid_f09  n nmiss mean min max;
   var q1-q17;
   output out=thesis.sef_sum (drop=_type_ _freq_);
run;

proc export data= thesis.sef_sum
   dbms=excel2000
   outfile="&dts.SEF_Overall_Average_Ratings_per_Statement.xls"
   replace;
   sheet="SEF_Summary_with_labels";
   label;
run;

proc univariate data= thesis.Studgrade_and_sef_by_cseid_f09;
      var q1-q17;
     histogram;
run;

options LINESIZE=120 PAGESIZE=60 nonumber nodate nocenter;
proc means data= thesis.Studgrade_and_sef_by_cseid_f09 n nmiss mean min max ;
   var &grad_dist;
   format _numeric_ 3.;
run;


options LINESIZE=120 PAGESIZE=60 nonumber nodate nocenter;
proc means data= thesis.Studgrade_and_sef_by_cseid_f09 n nmiss mean min max ;
   var Q1-Q17;
   format _numeric_ 3.;
run;

proc export data= thesis.grade_dist_summary
   dbms=excel2000
   outfile="&dts.Grade_Distr_Summary_Statistics.xls"
   replace;
   sheet="Grade_dist_summary";
   label;
run;

proc means data= thesis.Studgrade_and_sef_by_cseid_f09 n nmiss mean min max;
   var &msef;
run;


/* ------------------------------------------------------------------
      DEFINING THE DEVELOPMENT AND VALIDATION SAMPLES
-------------------------------------------------------------------*/

%macro dsattrn(ds);
   %global obsnum varsnum;
   %let dsid = %sysfunc(open(&ds));
   %if &dsid %then
      %do;
         %let obsnum =%sysfunc(attrn(&dsid,NOBS));
         %let varsnum=%sysfunc(attrn(&dsid,NVARS));
         %let clse = %sysfunc(close(&dsid));
```

```
        %put data set &ds open successful - %sysfunc(sysmsg());
       %end;
   %else
      %put Open for data set &ds failed - %sysfunc(sysmsg());
%mend dsattrn;
%dsattrn(thesis.Studgrade_and_sef_by_cseid_f09);

%let samprate=%sysevalf(2/3);
%let devsampsize=%sysfunc(round(%sysevalf(&obsnum*&samprate),1));
%let valsampsize=%eval(&obsnum-&devsampsize);


data thesis.Studgrade_and_sef_by_cseid_f09;
   retain devsampsize &devsampsize valsampsize &valsampsize;
   set thesis.Studgrade_and_sef_by_cseid_f09;
   randnum=ranuni(125689);
   devsamp=0;
   valsamp=0;
   if randnum <%sysevalf(&devsampsize/&obsnum) and devsampsize >0
      then do;
         devsamp=1;
         valsamp=0;
         devsampsize=devsampsize-1;
      end;
   else do;
         valsamp=1;
         devsamp=0;
      end;
   drop devsampsize valsampsize;
run;


data thesis.devsamp thesis.valsamp;
   set thesis.Studgrade_and_sef_by_cseid_f09;
   if devsamp=1 then output thesis.devsamp;
   else output thesis.valsamp;
run;

data thesis.devsamp;
   set thesis.devsamp;
   weight=%sysevalf(1/&samprate);
run;


data thesis.valsamp;
   set thesis.valsamp;
   weight=%sysevalf(1/(1-&samprate));
run;


data thesis.dev_and_val_samps;
   set thesis.Devsamp  thesis.Valsamp;
run;

proc means data= thesis.dev_and_val_samps sum;
   var  devsamp  valsamp;
run;
```

```
proc univariate data= thesis.Devsamp;
     var grade_avg sef_avg;
    histogram;
run;


proc univariate data= thesis.Devsamp;
      var q1-q17;
     histogram;
run;

proc format;
   value samptype
   1 = 'Devsamp'
   0 = 'Valsamp'
   ;
run;


proc freq data=   thesis.dev_and_val_samps;
   format   Devsamp  samptype.;
   tables sec*Devsamp /missing norow nocum nopercent nocol
out=thesis.strat_sec_freq;
run;

/***************************************************************************
**
   The sample obtained by the above process does not respect representation
   of all Course Sections, For this reason we use stratified sampling
****************************************************************************
**/



proc freq data=   thesis.Studgrade_and_sef_by_cseid_f09;
   tables sec /missing;
run;


data thesis.Studgrade_and_sef_by_cseid_f09;
   set thesis.Studgrade_and_sef_by_cseid_f09;
   stratsamp=1;
   if sec in ('0098', '2420') then stratsamp=0;
run;

proc sort data=thesis.Studgrade_and_sef_by_cseid_f09
out=Studgrade_and_sef_by_cseid (where=(stratsamp=1)); by sec; run;

proc surveyselect data =Studgrade_and_sef_by_cseid
   out = thesis.devsampstrat
   method = srs
    samprate = .65
   seed = 15678;
   strata sec;
run;
```

```
proc freq data=   thesis.devsampstrat;
   tables sec /missing;
run;

proc sort data=thesis.Studgrade_and_sef_by_cseid_f09
out=Studgrade_and_sef_by_cseid; by courseid; run;
proc sort data=thesis.devsampstrat out=devsampstrat; by courseid; run;

data thesis.Studgrade_and_sef_by_cseid_f09;
   merge Studgrade_and_sef_by_cseid (in=ina) devsampstrat (in=inb);
   by    courseid;
   devstratsamp=0; valstratsamp=0;
   if inb then devstratsamp=1;
   else if not inb and stratsamp=1 then valstratsamp=1;
   if ina;
run;


proc sort data=thesis.devsampstrat out=devsampstrat (keep=sec SelectionProb
rename=(SelectionProb=devSelectProb)) nodupkey ; by sec; run;
proc sort data=thesis.Studgrade_and_sef_by_cseid_f09; by sec; run;

data thesis.Studgrade_and_sef_by_cseid_f09 thesis.valsampstrat
(where=(valstratsamp=1));
   merge thesis.Studgrade_and_sef_by_cseid_f09 (in=ina)  devsampstrat
(in=inb);
   by sec;
   if valstratsamp=1 and inb then
      do;
         SelectionProb=1-devSelectProb;
         SamplingWeight=1/(1-devSelectProb);
      end;
   drop devSelectProb;
   if ina;
run;

proc format;
   value stratsamptype
   1 = 'devstratsamp'
   0 = 'valstratsamp'
   ;
run;

proc freq data=   thesis.Studgrade_and_sef_by_cseid_f09
(where=(stratsamp=1));
   format   devstratsamp  stratsamptype.;
   tables sec*devstratsamp /missing norow nocum nopercent nocol;
run;


proc means data=thesis.Studgrade_and_sef_by_cseid_f09 (where=(stratsamp=1))
sum mean n;
   class  devstratsamp sec;
   format   devstratsamp  stratsamptype.;
   var studno ;
```

```
run;


/* ---------------------------------------
   PRINCIPAL COMPONENTS ANALYSIS
-----------------------------------------*/

ods graphics on;
PROC FACTOR DATA=thesis.devsampstrat
   SIMPLE
   NFACTORS= 2
   METHOD=PRIN
   PRIORS=ONE
   MINEIGEN=.4
   SCREE
   ROTATE=VARIMAX
   ROUND
   FLAG=.35
   OUT= thesis.pca2stratdevsamp_sef;
   VAR &msef;
RUN;
ods graphics off;
title '';



/*-----------------------------------------------------------------------
   CORRELATIONS COEFFICIENTS BETWEEN SEF VARS AND GRADE AVERAGE VARS
-----------------------------------------------------------------------*/

title "Correlation Between PCA Factor of PCA and Grade Average";
ods graphics on;
proc corr data=thesis.pca2stratdevsamp_sef nomiss
          plots=scatter(alpha=.10 .20 .30);
   var grade_avg ; with factor1 factor2 ;
 run;
ods graphics off;
title '';

title "Pearson's Correlation Between SEF Variables and Grade Average";
ods graphics on;
proc corr data=thesis.devsampstrat nomiss
          plots=scatter(alpha=.10 .20 .30) out=thesis.pearsoncorr;
   var Q1-Q17 ; with grade_avg;
run;
ods graphics off;
title '';

proc export data= thesis.pearsoncorr
   dbms=excel2000
   outfile="&dts.Pearson Correlation Output.xls"
   replace;
run;


title "Spearman's Correlation Between SEF Variables and Grade Variables Non-
Strat. Sample";
```

```
ods graphics on;
proc corr data=thesis.devsampstrat nomiss Spearman
          plots=scatter(alpha=.10 .20 .30) out=thesis.SpearmanCorr;
   var Q1-Q17 ; with grade_avg;
run;
ods graphics off;
title '';


proc export data= thesis.SpearmanCorr
   dbms=excel2000
   outfile="&dts.Spearman Correlation Output.xls"
   replace;
run;

title "Kendall's Correlation Between SEF Variables and Grade Variables Non-
Strat. Sample";
ods graphics on;
proc corr data=thesis.devsampstrat nomiss Kendall
          plots=scatter(alpha=.10 .20 .30) out=thesis.KendallCorr;
   var Q1-Q17 ; with grade_avg;
run;
ods graphics off;
title '';


proc export data= thesis.KendallCorr
   dbms=excel2000
   outfile="&dts.Kendall Correlation Output.xls"
   replace;
run;


/* ---------------------------------------
   LINEAR REGRESSION MODEL DEVELOPMENT
-----------------------------------------*/

* 1. Regression with the principal components;

%let pvalue=0.05;

proc reg data=thesis.pca2stratdevsamp_sef;
   model grade_avg=factor1 factor2 /noint selection=stepwise slentry=&pvalue;
run; quit;

title1 'Linear Regression for grade_avg as Dependent Variable';
title2 '          and SEF as Predictors';


* 2. Regression with the Student Evaluation of Faculty Variables;

proc reg data=thesis.devsampstrat;
   model grade_avg=&msef /noint selection=stepwise slentry=&pvalue;
run; quit;


ods graphics on;
```

```
proc reg data=thesis.devsampstrat;
   model grade_avg=Q1 Q8 Q10 Q11 /noint  rsquare bic aic collin collinoint
corrb vif OUTVIF ;
   output out=thesis.output_reg p=pred_gradavg STUDENT=studzd_resid r=resid
RSTUDENT=rstud COOKD=cookdstat DFFITS=dffits;
   plot student.*predicted.;
   plot npp.*r.;
   plot r.*p.;
   plot r.*(q6 q10);
run;
ods graphics off;


*3. Adding Interaction terms into the linear model;

data  thesis.devsampstrat;
   set thesis.devsampstrat;
   intQ1Q8=Q1*Q8;
   intQ1Q10=Q1*Q10;
   intQ1Q11=Q1*Q11;
   intQ8Q10=Q8*Q10;
   intQ8Q11=Q8*Q11;
   intQ10Q11=Q10*Q11;
   intQ1Q8Q10=Q1*Q8*Q10;
   intQ1Q8Q11=Q1*Q8*Q11;
      intQ8Q10Q11=Q8*Q10*Q11;
run;

title 'All interaction terms in the model';
proc reg data=thesis.devsampstrat;
   model grade_avg=Q1 Q8 Q10 Q11 intQ1Q8 intQ1Q10 intQ1Q11 intQ8Q10 intQ8Q11
intQ10Q11 intQ1Q8Q10 intQ1Q8Q11 intQ8Q10Q11 /noint  rsquare bic aic vif;
run; quit;


title 'The model with interaction term intQ10Q11 removed';

proc reg data=thesis.devsampstrat;
   model grade_avg=Q1 Q8 Q10 Q11 intQ1Q8 intQ1Q10 intQ1Q11 intQ8Q10 intQ8Q11
intQ1Q8Q10 intQ1Q8Q11 intQ8Q10Q11 /noint  rsquare bic aic vif;
run; quit;


title 'The model with interaction term intQ8Q10Q11 removed';
proc reg data=thesis.devsampstrat;
   model grade_avg=Q1 Q8 Q10 Q11 intQ1Q8 intQ1Q10 intQ1Q11 intQ8Q10 intQ8Q11
intQ1Q8Q10 intQ1Q8Q11 /noint  rsquare bic aic vif;
run; quit;


title 'The model with interaction term intq8q11 removed';
proc reg data=thesis.devsampstrat;
   model grade_avg=Q1 Q8 Q10 Q11 intQ1Q8 intQ1Q10 intQ1Q11 intQ8Q10
intQ1Q8Q10 intQ1Q8Q11 /noint  rsquare bic aic vif;
run; quit;
```

```
title 'The model with interaction term intQ1Q8Q10 removed';
proc reg data=thesis.devsampstrat;
   model grade_avg=Q1 Q8 Q10 Q11 intQ1Q8 intQ1Q10 intQ1Q11 intQ8Q10
intQ1Q8Q11 /noint  rsquare bic aic vif;
run; quit;


title 'The model with interaction term intq1q10 removed';
proc reg data=thesis.devsampstrat;
   model grade_avg=Q1 Q8 Q10 Q11 intQ1Q8 intQ1Q11 intQ8Q10 intQ1Q8Q11 /noint
rsquare bic aic vif;
run; quit;

title 'The model with interaction term intq8q10 removed';
proc reg data=thesis.devsampstrat;
   model grade_avg=Q1 Q8 Q10 Q11 intQ1Q8 intQ1Q11 intQ1Q8Q11 /noint  rsquare
bic aic vif ;
run; quit;


title 'The model with interaction term intq1q8 removed';
proc reg data=thesis.devsampstrat;
   model grade_avg=Q1 Q8 Q10 Q11 intQ1Q11 intQ1Q8Q11 /noint  rsquare bic aic
vif ;
run; quit;


title 'The model with interaction term intQ1Q8Q11 removed';
proc reg data=thesis.devsampstrat;
   model grade_avg=Q1 Q8 Q10 Q11 intQ1Q11 /noint  rsquare bic aic vif ;
run; quit;


title 'The model with interaction term intQ1Q11 removed';
proc reg data=thesis.devsampstrat;
   model grade_avg=Q1 Q8 Q10 Q11 /noint  rsquare bic aic vif;
run; quit;

* We obtain the same model we had before adding interaction terms;


/*-----------------------------------------------------------------------------
4. Transformation of the Dependent Variable and Independent Variables
   to Try and Stabilize Errors Variances
----------------------------------------------------------------------------
*/

data thesis.devsampstrat;
   set thesis.devsampstrat;
   length logy Sq1-Sq17 CubQ1-CubQ17 LogQ1-LogQ17 8.;
   logy=log(grade_avg);
   Sq1=Q1**2;
   Sq1=Q1**2;  CubQ1=Q1**3;   LogQ1=log(Q1);
   Sq2=Q2**2;  CubQ2=Q2**3;   LogQ2=log(Q2);
   Sq3=Q3**2;  CubQ3=Q3**3;   LogQ3=log(Q3);
   Sq4=Q4**2;  CubQ4=Q4**3;   LogQ4=log(Q4);
   Sq5=Q5**2;  CubQ5=Q5**3;   LogQ5=log(Q5);
```

```
   Sq6=Q6**2;  CubQ6=Q6**3;   LogQ6=log(Q6);
   Sq7=Q7**2;  CubQ7=Q7**3;   LogQ7=log(Q7);
   Sq8=Q8**2;  CubQ8=Q8**3;   LogQ8=log(Q8);
   Sq9=Q9**2;  CubQ9=Q9**3;   LogQ9=log(Q9);
   Sq10=Q10**2; CubQ10=Q10**3; LogQ10=log(Q10);
   Sq11=Q11**2; CubQ11=Q11**3; LogQ11=log(Q11);
   Sq12=Q12**2; CubQ12=Q12**3; LogQ12=log(Q12);
   Sq13=Q13**2; CubQ13=Q13**3; LogQ13=log(Q13);
   Sq14=Q14**2; CubQ14=Q14**3; LogQ14=log(Q14);
   Sq15=Q15**2; CubQ15=Q15**3; LogQ15=log(Q15);
   Sq16=Q16**2; CubQ16=Q16**3; LogQ16=log(Q16);
   Sq17=Q17**2; CubQ17=Q17**3; LogQ17=log(Q17);
run;

proc reg data=thesis.devsampstrat;
   model logy=&msef Sq1-Sq17 CubQ1-CubQ17 LogQ1-LogQ17
            / selection=stepwise slentry=&pvalue;
run; quit;


ods graphics on;
   title 'Model with Transformations: Q3 CubQ9 CubQ10 CubQ11 LogQ4 LogQ7 in';
proc reg data=thesis.devsampstrat;;
   model logy=Q3 CubQ9 CubQ10 CubQ11 LogQ4 LogQ7 /rsquare bic aic collin
collinoint corrb vif OUTVIF ;
   output out=thesis.regout_int_varioustransf p=pred_gradavg
STUDENT=studzd_resid r=resid RSTUDENT=rstud COOKD=cookdstat DFFITS=dffits;
   plot student.*predicted.;
   plot npp.*r.;
   plot r.*p.;
   plot r.*(Q3 CubQ9 CubQ10 CubQ11 LogQ4 LogQ7);
run;
ods graphics off;


/* ---------------------------------------------------------------------------
   The Model:
   logy=1.69131+0.44930*Q3-0.00672*CubQ9+0.00730*CubQ10+0.00413*CubQ11-
   1.63290*LogQ4-0.55153*LogQ7;
---------------------------------------------------------------------------*/

proc univariate data= thesis.regout_int_varioustransf;
   var  resid;
   histogram/normal;
run;


/* Validation with Validation Sample */

proc sort data=thesis.valsampstrat;by courseid; run;

data thesis.valsampstrat;
   set thesis.valsampstrat;
   boxcox_grade_avg=grade_avg**1.5;
   CubQ9=Q9**3;
   CubQ10=Q10**3;
   CubQ11=Q11**3;
```

```
   LogQ4=log(Q4);
   LogQ7=log(Q7);
   logy=1.69131+0.44930*Q3-0.00672*CubQ9+0.00730*CubQ10+0.00413*CubQ11-
1.63290*LogQ4-0.55153*LogQ7;
   pred_gradavg_vartransf=exp(1.69131+0.44930*Q3-
0.00672*CubQ9+0.00730*CubQ10+0.00413*CubQ11-1.63290*LogQ4-0.55153*LogQ7);
   pred_err_vartransf= grade_avg - pred_gradavg_vartransf;
run;

proc export data= thesis.valsampstrat (keep=CourseId grade_avg    logy  Q3
CubQ9 CubQ10 CubQ11 LogQ4 LogQ7
         pred_gradavg_vartransf  pred_err_vartransf)
dbms=excel2000
outfile="&dts.Validation for Model with Variable Transformations.xls"
replace;
sheet='Model Validation';
run;

/*************************************************************************
   LOGISTIC REGRESSION MODEL WITH CATEGORICAL VARIABLES FOR MATH LEVELS
*************************************************************************/

/*    In building the logistic regression model, we consider proportion of
students with a grade of A+ to B (High Performance, hperf) versus proportion
of students with a grade of B- to F (low performance:1-hperf);
   If hperf >= 0.4 then categorical variable hp40=1, else hp40=0;
*/

data thesis.devsampstrat;
   set thesis.devsampstrat;
   hperf=sum(Aplus,A,Aminus,Bplus,B)/sum(Aplus,A,Aminus,Bplus,B,Bminus,Cplus,
C,Cminus,D,F);
   hp40 = (hperf>=0.40);
   hp50 = (hperf>=0.50);
   hp60 = (hperf>=0.60);
   label hperf='Proportion of high performance (% of student with grade >=
B';
   label hp40='Indicator of High Performance Above 40%, hp40=1 if hperf>=0.4,
else hp40=0';
   label hp50='Indicator of High Performance Above 50%, hp50=1 if hperf>=0.5,
else hp50=0';
   label hp60='Indicator of High Performance Above 60%, hp60=1 if hperf>=0.6,
else hp60=0';
   length math 3.;
   math=0;
   if sec in ('2008',   '2211',  '2212',  '2215',  '2420') then math=1;
   else math=0;
run;

data thesis.valsampstrat;
   set thesis.valsampstrat;
   hperf=
sum(Aplus,A,Aminus,Bplus,B)/sum(Aplus,A,Aminus,Bplus,B,Bminus,Cplus,C,Cminus,
D,F);
   hp40 = (hperf>=0.40);
   hp50 = (hperf>=0.50);
   hp60 = (hperf>=0.60);
```

```
   label hperf='Proportion of high performance (% of student with grade >=
B';
   label hp40='Indicator of High Performance Above 40%, hp40=1 if hperf>=0.4,
else hp40=0';
   label hp50='Indicator of High Performance Above 50%, hp50=1 if hperf>=0.5,
else hp50=0';
   label hp60='Indicator of High Performance Above 60%, hp60=1 if hperf>=0.6,
else hp60=0';
   length math 3.;
   math=0;
   if sec in ('2008',   '2211',   '2212',   '2215',   '2420') then math=1;
   else math=0;
run;

Title 'LOGISTIC REGRESSION MODEL WITH CATEGORICAL VARIABLE FOR HIGH
PERFORMANCE OVER 40%';

proc logistic data=  thesis.devsampstrat descending alpha=&pvalue;
 model hp40 = q1-q17 math / selection=b  CTABLE pprob= (0.2 to 0.8 by 0.1)
lackfit rl ;
run;

proc logistic data=  thesis.devsampstrat descending alpha=&pvalue
outest=thesis.hp40_logist_param_estim;
   model hp40 = Q9 Q11 Q16 Math/COVB CORRB rsquare CTABLE pprob= (0.2 to 0.8
by 0.1) lackfit rl;
   output out=thesis.hp40_regoutput p=score;
run;

data  thesis.hp40_regoutput;
   set thesis.hp40_regoutput;
   if score >= 0.4 then pred_hp40=1;
   else  pred_hp40=0;
   if hp40=pred_hp40 then concord=1;
   else concord=0;
run;

proc freq data =  thesis.hp40_regoutput;
tables hp40 * pred_hp40/norow nocol;
run;

proc score data=thesis.devsampstrat (keep= courseid Q9 Q11 Q16 Math hp40
hperf rename=(hp40=act_hp40))
   score=thesis.hp40_logist_param_estim out=thesis.hp40_DevSamp_Scoreout
(rename=(hp40=score)) type=parms;
   var  Q9 Q11 Q16 Math;
run;

data  thesis.hp40_DevSamp_Scoreout;
   set thesis.hp40_DevSamp_Scoreout;
   hp40_score=exp(score)/(1+exp(score));
   hp40_score1=1/(1+exp(-(- 7.1988 - 2.1322*Q9 + 2.7178*Q11 + 1.8425*Q16 -
4.0660*math)));
   if hp40_score >= 0.4 then pred_hp40=1;
   else  pred_hp40=0;
   if act_hp40=pred_hp40 then concord=1;
   else concord=0;
```

```
run;

proc freq data =  thesis.hp40_DevSamp_Scoreout;
   tables act_hp40 * pred_hp40/norow nocol;
run;


/**********************************************************************
   VALIDATION OF THE LOGISTIC MODEL WITH VALIDATION/HOLDOUT SAMPLE
**********************************************************************/

proc score data=thesis.valsampstrat (keep= courseid Q9 Q11 Q16 Math hp40
hperf rename=(hp40=act_hp40))
   score=thesis.hp40_logist_param_estim out=thesis.hp40_ValSamp_Scoreout
(rename=(hp40=score)) type=parms;
   var Q9 Q11 Q16 Math;
run;

data  thesis.hp40_ValSamp_Scoreout;
   set thesis.hp40_ValSamp_Scoreout;
   hp40_score=exp(score)/(1+exp(score));
   hp40_score1=1/(1+exp(-(- 7.1988 - 2.1322*Q9 + 2.7178*Q11 + 1.8425*Q16 -
4.0660*math)));
   if hp40_score >= 0.4 then pred_hp40=1;
   else  pred_hp40=0;
   if act_hp40=pred_hp40 then concord=1;
   else concord=0;
run;


proc freq data =  thesis.hp40_ValSamp_Scoreout;
tables act_hp40 * pred_hp40/norow nocol;
run;


/***************************************
   SCORING THE WHOLE SAMPLE
****************************************/

data thesis.WholeSample;
   set  thesis.devsampstrat thesis.valsampstrat;
   keep sec courseid Q9 Q11 Q16 Math hperf hp40;
   rename hp40=act_hp40;
run;


proc score data=thesis.WholeSample
   score=thesis.hp40_logist_param_estim out=thesis.hp40_WholeSample_Scoreout
(rename=(hp40=score)) type=parms;
   var Q9 Q11 Q16 Math;
run;


data  thesis.hp40_WholeSample_Scoreout;
   set thesis.hp40_WholeSample_Scoreout;
   pred_hperf_score=exp(score)/(1+exp(score));
```

```
   pred_hperf_score1=1/(1+exp(-(- 7.1988 - 2.1322*Q9 + 2.7178*Q11 +
1.8425*Q16 - 4.0660*math)));
   if pred_hperf_score >= 0.4 then pred_hp40=1;
   else  pred_hp40=0;
   if act_hp40=pred_hp40 then concord=1;
   else concord=0;
run;


proc freq data =  thesis.hp40_WholeSample_Scoreout;
tables act_hp40 * pred_hp40/norow nocol;
run;

proc export data=thesis.hp40_WholeSample_Scoreout
   dbms=excel2000
   outfile="&dts.Logistic Model Scores.xls"
   replace;
   sheet='Scores';
run;
```